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REEDFAX Reference Report									
Patent Bibliographic Information					Check References Activity				
Pat. No.	Title	Inventor	Date	Assignee	Any	Notices of Litigation, Reqs for Reexamination	Expirations, Extensions, Withdrawals	Reissues, Reexam Certificates	Certs of Correction, Disclaims, Dedications
7,179,046	Fan array fan section in air-handling systems	Hopkins	2/20/07	Huntair Inc., Tualatin, Oregon, United States (US), United States company or corporation (02)	--				
7,137,775	Fan array fan section in air-handling systems	Hopkins	11/21/06	Huntair Inc., Tualatin, Oregon, United States (US), United States company or corporation (02)	--				
6,792,766	Zone demand controlled dual air conditioning system and controller therefor	Osborne et al.	9/21/04	Cascade Manufacturing, L.P., Richardson, Texas, Y United States (US), United States company or corporation (02)					March 15, 2005 - a Certificate of Correction was issued for this patent (O.G. April 5, 2005)
6,675,739	Livestock cooling system	Terrell et al.	1/13/04		Y	NOTICE OF LITIGATION  Schafer Ventilation System v. Korral Kool Inc, Filed February 14, 2005, D.C. Minnesota, Doc. No. 0:05cv328			
6,648,590	Parallel fan	Huang et al.	11/18/03	Delta Electronics, Inc., Taoyuan Hsien, Taiwan (TW), Foreign company or corporation (03)	--				
6,463,891	Twin fan control system and method	Algrain et al.	10/15/02	Caterpillar Inc., Peoria, Illinois, United States (US), United States company or corporation (02)	--				
6,436,130	Cooling system for therapeutic catheter	Philips et al.	8/20/02	Alsus Corporation, Irvine, California, United States (US), United States company or corporation (02)	--				
6,427,455	Cooling device and its cooling method	Furubayashi	8/6/02	January 28, 2005 - CHANGE OF NAME (SEE DOCUMENT FOR DETAILS)., AIR OPERATION TECHNOLOGIES INC. 4-10, HIKOSHIMASAKOMACHI 1-CHOME, SHIMONOSEKI-SHIYAMAGUCHI 750-0092, (1), Reel and Frame Number: 015629/0432	Y				May 27, 2003 - a Certificate of Correction was issued for this patent (O.G. June 17, 2003)
6,414,845	Multiple-fan modular cooling component Bonet		7/2/02	Hewlett-Packard Co., Palo Alto, California, United States (US), United States company or corporation (02)	--				
6,407,918	Series-parallel fan system	Edmunds et al.	6/18/02	July 30, 2002 - ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS)., GENERAL ELECTRIC COMPANY 1 RIVER ROADSCHENECTADY, NEW YORK, 12345, Reel and Frame Number: 013443/0445	--				
6,388,880	Removable fan tray assembly with latching features	El-Ghobashy et al.	5/14/02	Fijitsu Network Communications, Inc., Richardson, Texas, United States (US), United States company or corporation (02)	--				
6,386,969	Garage ventilation system	O'Brien	5/14/02		Y		May 14, 2006 - due to failure to pay maintenance fees. (O.G. July 11, 2006)		
6,386,826	Fan with self closing blades	Jacob	5/14/02	International Business Machines Corporation, Armonk, New York, United States (US), United States company or corporation (02)	--				
6,257,832	Multiple fan system having means for reducing beat frequency oscillations	Lyszkowski et al.	7/10/01	Dell USA, L.P., Round Rock, Texas, United States (US), United States company or corporation (02)	--				

6,155,335 Vehicle fan shroud and component cooling module	Acre et al.	12/5/00 Delphi Technologies, Inc., Troy, Michigan, United States (US), United States company or corporation (02)	--		
6,072,397 Method and apparatus for reducing flame emissions from an electronics enclosure	Ostrowski	6/6/00 Ascend Communications, Inc., Alameda, California, United States (US), United States company or corporation (02)	Y	June 6, 2004 - due to failure to pay maintenance fees. (O.G. August 3, 2004)	
6,031,717 Back flow limiting device for failed redundant parallel fan	Baddour et al.	2/29/00 Dell USA, L.P., Round Rock, Texas, United States (US), United States company or corporation (02)	Y		May 28, 2002 - a Certificate of Correction was issued for this patent (O.G. June 18, 2002)
5,793,610 Multi-position air regulation device	Schmitt et al.	8/11/98 Dell USA, L.P., Round Rock, Texas, United States (US), United States company or corporation (02)	Y		April 29, 2003 - a Certificate of Correction was issued for this patent (O.G. May 20, 2003)
5,787,971 Multiple fan cooling device	Dodson	8/4/98 June 11, 2007 - ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS)., OCZ TECHNOLOGY GROUP, INC. 860 E. ARQUES AVENUE SUNNYVALE CALIFORNIA 94085, Reel and Frame Number: 019407/0072	Y	August 4, 2002 - due to failure to pay maintenance fees (O.G. October 1, 2002)	
5,745,041 System for dissipating heat from a power supply	Moss	4/28/98 Dell U.S.A., L.P., Austin, Texas, United States (US), United States company or corporation (02)	--		
5,701,750 Zone demand controlled dual heat pump system and controller therefor	Ray	12/30/97	--		
5,664,995 Environmental enclosure apparatus with air flow control and balancing	O'Keefe	9/9/97 O.K. Filters Company, Inc., Troy, New York, United States (US), United States company or corporation (02)	Y	September 9, 2005 - due to failure to pay maintenance fees. (O.G. November 8, 2005)	
5,632,677 Fan-equipped air delivery vent	Elkins	5/27/97	--		
5,572,403 Plenum bypass serial fan cooling subsystem for computer systems	Mills	11/5/96 Dell USA, L.P., Austin, Texas, United States (US), -- United States company or corporation (02)	--		
5,546,272 Serial fan cooling subsystem for computer systems	Moss et al.	8/13/96 Dell USA, L.P., Austin, Texas, United States (US), -- United States company or corporation (02)	--		
5,370,576 Sidewall vent-mounted fan assembly for Krofchalk a truck cab		12/6/94 Sackett, Eleanor L., Stewartville, Minnesota, United States (US), United States individual (04) Krofchalk, Jon W., Winona, Minnesota, United States (US), United States individual (04)	Y	December 6, 2002 - due to failure to pay maintenance fees. (O.G. February 4, 2003)	
5,269,660 Method and an installation for adjusting the flow rate of air in a network of ducts	Pradelle	12/14/93 Compagnie Generale des Matieres Nucleaires, Velizy Villacoublay, France (FR), Foreign company or corporation (03)	Y	December 14, 2001 - due to failure to pay maintenance fees (O.G. February 19, 2002)	
5,210,680 Card cage having an air cooling system	Scheibler	5/11/93 Sulzer Brothers Limited, Winterthur, Switzerland (CH), Foreign company or corporation (03)	--		
5,136,465 Personal computer with tandem air flow dual fans and baffle directed air cooling	Benck et al.	8/4/92 August 4, 2005 - ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS)., LENOVO (SINGAPORE) PTE LTD. 7, CHANGI BUSINESS PARK CENTRAL 1 SINGAPORE 486048 , Reel and Frame Number: 016891/0507	Y	August 4, 2000 - due to failure to pay maintenance fees (O.G. October 10, 2000)	

4,800,653 Method and apparatus for controlling the drying and cooling of field-harvested seeds in storage	Steffen	1/31/89	--	
4,767,262 Fan slide-in unit	Simon	8/30/88 Knurr-Mechanik Fur Die Elektronik Aktiengesellschaft, Munich, Germany (DE), Foreign company or corporation (03)	Y	August 30, 2000 - due to failure to pay maintenance fees (O.G. October 31, 2000)
4,651,922 Apparatus for controlling rotational speed of radiator fan	Noba	3/24/87 Toyota Jidosha Kabushiki Kaisha, Aichi, Japan (JP), Foreign company or corporation (03)	Y	March 29, 1995 - due to failure to pay maintenance fees.
4,494,006 Method and apparatus for controlling a multicompressor station	Staroselsky et al.	1/15/85 November 2, 1992 - ASSIGNMENT OF ASSIGNORS INTEREST., BANK SOUTH, N.A. 55 MARIETTA STREET, N.W.ATLANTA, GEORGIA, 30303, Reel and Frame Number: 006289/0760 November 2, 1992 - SECURITY INTEREST (SEE DOCUMENT FOR DETAILS)., BANK SOUTH, N.A. 55 MARIETTA STREET, N.W.ATLANTA, GEORGIA, 30303, Reel and Frame Number: 006290/0062 June 16, 1999 - ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS)., ROPER HOLDINGS, INC. SUITE 1704 300 DELAWARE AVENUEWILMINGTON, DELAWARE, 19801, Reel and Frame Number: 010024/0199 December 23, 2003 - ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS)., COMPRESSOR CONTROLS CORPORATION 4725 121ST STREETDES MOINES, IOWA, 50323, Reel and Frame Number: 014822/0013 December 23, 2003 - ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS)., ROPINTASSCO 4, LLC 2160 SATELLITE BLVD., SUITE 200DULUTH, GEORGIA, 30097, Reel and Frame Number: 014822/0039 December 23, 2003 - ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS)., ROPINTASSCO HOLDINGS, L.P. 2160 SATELLITE BLVD.DULUTH,	--	
4,426,960 Control circuitry for multistage fans	Hart	1/24/84 Square D Company, Palatine, Illinois, United States (US), United States company or corporation (02)	--	
4,241,871 Apparatus and method for ventilation of animal enclosures	Newell et al.	12/30/80 January 26, 1981 - ASSIGNMENT OF ASSIGNORS INTEREST., CITIES SERVICE COMPANY, 110 WEST SEVENTH, P.O. BOX 300, TULSA, OK. 74102, A CORP. OF DE., Reel and Frame Number: 003826/0510	--	

4,158,527 Adjustable speed drive system for centrifugal fan	Burkett	6/19/79 April 11, 1985 - SECURITY INTEREST (SEE DOCUMENT FOR DETAILS)., CITIBANK,N.A., 641 LEXINGTON AVENUE,NEW YORK,NEW YORK 10043, Reel and Frame Number: 004392/0727 August 30, 1985 - SECURITY INTEREST (SEE DOCUMENT FOR DETAILS)., PHILADELPHIA NATIONAL BANK, THE, BROAD AND CHESTNUT STREETS, PHILADELPHIA, PA. 19101, Reel and Frame Number: 004458/0203 September 6, 1985 - RELEASED BY SECURED PARTY (SEE DOCUMENT FOR DETAILS)., ECOLAIRE PRIME, INC., A DE CORP., ECOLAIRE INCORPORATED A PA CORP., Reel and Frame Number: 004455/0898 June 1, 1987 - ASSIGNMENT OF ASSIGNORS INTEREST., JOY TECHNOLOGIES INC., 301 GRANT STREET, PITTSBURGH, PA. 15219 A DE. CORP., Reel and Frame Number: 004718/0963 June 11, 1987 - ASSIGNMENT OF ASSIGNORS INTEREST., ECOLAIRE INCORPORATED, GREAT VALLEY CONTER, 1 COUNTRY VIEW RD., MALVERN, PA 19355 A CORP. OF PA, Reel and Frame Number: 004723/0617 June 30, 1987 - ASSIGNMENT OF ASSIGNORS INTEREST., CITIBANK, N.A., 641 LEXINGTON, AVE., NEW YORK, NY 10043, Reel and Frame Number: 004749/0032 November 17, 1987 - RELEASE OF PATENTS IN SECURITY AGREEMENT DATED AUGUST 30, 1 October 27, 1989 - RELEASED BY SECURED PA	--	
4,133,374 Heat exchanger	York	1/9/79 Smith Engineering Company, South El Monte, California, United States (US), United States company or corporation (02)	Y	April 20, 1987 - Disclaimer filed by the assignee, Smith Engineering Co., Hereby enters this disclaimer to claim 1 of said patent.

4,021,213 Food storage refrigeration cabinet having optional fast chill cycle	Neidhardt et al.	5/3/77	October 24, 1980 - ASSIGNMENT OF ASSIGNORS INTEREST., INTERNATIONAL FOODSERVICE EQUIPMENT SYSTEMS, INC., NEW YORK, N. Y., A CORP. OF DE, Reel and Frame Number: 003808/0584 October 27, 1980 - SECURITY INTEREST (SEE DOCUMENT FOR DETAILS)., CONGRESS FINANCIAL CORPORATION, Reel and Frame Number: 003808/0804 April 5, 1984 - CHANGE OF NAME (SEE DOCUMENT FOR DETAILS). EFFECTIVE DATE 02/09/82, BASTIAN ADVANCED SYSTEM, INC., Reel and Frame Number: 004245/0581 April 12, 1985 - SECURITY INTEREST (SEE DOCUMENT FOR DETAILS)., GENERAL ELECTRIC CREDIT CORPORATION, 260 LONG RIDGE ROAD, STAMFORD, CONNECTICUT 06902, A CORP. OF NEW YORK, Reel and Frame Number: 004387/0714 April 12, 1985 - RELEASED BY SECURED PARTY (SEE DOCUMENT FOR DETAILS)., BIH FOODSERVICE, INC., FORMERLY KNOWN AS INTERNATIONAL FOODSERVICE EQUIPMENT SYSTEMS, INC., Reel and Frame Number: 004392/0760 May 21, 1985 - SECURITY INTEREST (SEE DOCUMENT FOR DETAILS)., GENERAL ELECTRIC CREDIT CORPORATION, 260 LONG RIDGE ROAD, STAMFORD, CT. 06902 A NY CORP., Reel and Frame Number: 004404/0344 December 19, 1985 - ASSIGNMENT OF ASSIGN	--
3,898,019 AIR FAN APPARATUS	Reznick et al.	8/5/75	REZNICK DAVID E;; FEKETE ERNOE A, ()	--
3,332,621 Automatic control means	CHARLES	7/25/67		--
3,156,233 Sealing and sound absorbing means for air handling apparatus	O'CONNELL	11/10/64		--



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## **REEDFAX Claim Tree (7137775)**

### **Claim References by Claim**

- Claim 1
  - Claim 2
    - Claim 3
    - Claim 4
    - Claim 5
  - Claim 6
  - Claim 7
  - Claim 8
  - Claim 9
  - Claim 10
  - Claim 11
  - Claim 12
  - Claim 13
  - Claim 14
- Claim 15
  - Claim 16
    - Claim 17
    - Claim 18
- Claim 19

US00713775B2

(12) **United States Patent  
Hopkins**(10) **Patent No.:** US 7,137,775 B2  
(45) **Date of Patent:** Nov. 21, 2006(54) **FAN ARRAY FAN SECTION IN  
AIR-HANDLING SYSTEMS**(75) Inventor: **Lawrence G. Hopkins**, Portland, OR  
(US)(73) Assignee: **Huntair Inc.**, Tualatin, OR (US)(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.(21) Appl. No.: **10/806,775**(22) Filed: **Mar. 22, 2004**(65) **Prior Publication Data**

US 2004/0185771 A1 Sep. 23, 2004

**Related U.S. Application Data**(63) Continuation-in-part of application No. PCT/US04/  
08578, filed on Mar. 19, 2004.(60) Provisional application No. 60/554,702, filed on Mar.  
20, 2004, provisional application No. 60/456,413,  
filed on Mar. 20, 2003.(51) **Int. Cl.**  
**F04D 25/16** (2006.01)(52) **U.S. Cl.** ..... **415/61**; 415/119; 416/120;  
417/3; 417/423.5; 417/426(58) **Field of Classification Search** ..... 415/60,  
415/61, 108, 177, 119; 416/120; 417/3,  
417/423.5, 426; 454/338

See application file for complete search history.

(56) **References Cited****U.S. PATENT DOCUMENTS**

3,156,233 A	11/1964	O'Connell	126/110
3,332,621 A	7/1967	Tanner	
3,898,019 A	8/1975	Reznick et al.	
4,021,213 A	5/1977	Neidhardt et al.	62/180
4,133,374 A	1/1979	York	
4,158,527 A	6/1979	Burkett	

4,241,871 A	12/1980	Newell, III et al.	
4,426,960 A	1/1984	Hart	
4,494,006 A	1/1985	Staroselsky et al.	
4,651,922 A *	3/1987	Noba	236/35
4,767,262 A *	8/1988	Simon	415/119
4,800,653 A	1/1989	Steffen	
5,136,465 A	8/1992	Benck et al.	
5,210,680 A	5/1993	Scheibler	
5,269,660 A	12/1993	Pradelle	
5,370,576 A *	12/1994	Krofchalk	454/143
5,546,272 A	8/1996	Moss et al.	
5,572,403 A	11/1996	Mills	
5,632,677 A	5/1997	Elkins	
5,664,995 A	9/1997	O'Keefe	
5,701,750 A	12/1997	Ray	62/160

(Continued)

**FOREIGN PATENT DOCUMENTS**

EP 0205979 A1 12/1986

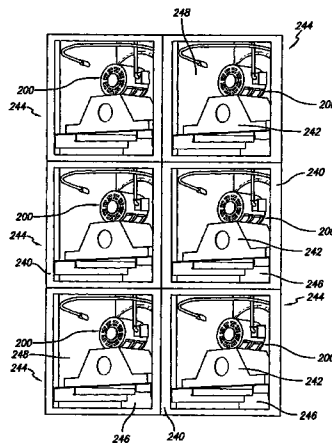
**OTHER PUBLICATIONS**

AAON, RL Series Rooftop Conditioners, Sep. 2001.

(Continued)

*Primary Examiner*—Ninh H. Nguyen(74) *Attorney, Agent, or Firm*—Silicon Valley Patent Group  
LLP(57) **ABSTRACT**

A fan array fan section in an air-handling system includes a plurality of fan units arranged in a fan array and positioned within an air-handling compartment. One preferred embodiment may include an array controller programmed to operate the plurality of fan units at peak efficiency. The plurality of fan units may be arranged in a true array configuration, a spaced pattern array configuration, a checker board array configuration, rows slightly offset array configuration, columns slightly offset array configuration, or a staggered array configuration.

**30 Claims, 15 Drawing Sheets**



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## U.S. PATENT DOCUMENTS

5,745,041	A	4/1998	Moss	
5,787,971	A	8/1998	Dodson	
5,788,568	A	8/1998	Ito et al.	454/188
5,793,610	A	8/1998	Schmitt et al.	
6,031,717	A	2/2000	Baddour et al.	
6,072,397	A *	6/2000	Ostrowski	340/588
6,155,335	A	12/2000	Acre et al.	
6,257,832	B1	7/2001	Lyskowski et al.	
6,386,826	B1	5/2002	Jacob	
6,386,969	B1	5/2002	O'Brien	
6,388,880	B1	5/2002	El-Ghobashy et al.	
6,407,918	B1	6/2002	Edmunds et al.	
6,414,845	B1	7/2002	Bonet	
6,427,455	B1	8/2002	Furubayashi	
6,436,130	B1	8/2002	Philips et al.	
6,463,891	B1	10/2002	Algrain et al.	
6,648,590	B1	11/2003	Huang et al.	
6,675,739	B1	1/2004	Terrell et al.	
6,791,836	B1	9/2004	Cipolla et al.	361/687
6,792,766	B1	9/2004	Osborne et al.	62/159
6,961,248	B1	11/2005	Vincent et al.	361/796
2005/0180846	A1	8/2005	Hopkins	415/119
2005/0232753	A1	10/2005	Hopkins	415/119

## OTHER PUBLICATIONS

Jim Parro (Marketing Mananager for AAON) New Promotional Literature The RL Series.

AAON, RL Series 45 to 230 tons Packaged Rooftop Conditioners & Air Handlers.

AAON, Invocie No. 265184, Feb. 28, 2002.

AAON, Order Form and Associated Documents, Nov. 14, 2001.

Osborne, W.C. and Turner, C.G., co-editors, "Woods Practical Guide to Fan Engineering," 1964, cover pages and pp. 121, 137-138, 146-148, 208, and 218, Benham and Company, Colchester, England.

Wilcke, William F. and Morey, R. Vance, "Selecting Fans, Determining Airflow for Crop Drying, Cooling, Storage," 1998, 8 pages, Regents of the University of Minnesota.

The Parallel and Series Operation, Sunon Group web page, <http://www.sunon.com/english/wealthtech/tech-06.htm>, at least as early as Mar. 15, 2004, 2 pages, Sunon Group, Taiwan.

Series and Parallel Fans, HighBeam Research web page, [www://static.highbeam.com/m/machinedesign/january261995/seriesandparallelfans/index.htm](http://www.static.highbeam.com/m/machinedesign/january261995/seriesandparallelfans/index.htm), Jan. 26, 1995, 1 page, HighBeam Research, LLC.

McLeod, Ian, Using Fans in Series and Parallel: Performance Guidelines, ebmpapst web page, <http://www.papstplc.com/features/articles/art006&print=true>, at least as early as Mar. 15, 2004, 3 pages, emb-Papst Automotive and Drives (UK) Ltd., UK.

Technical Bulletin: CLEANPAK M/R/PF Multi/Redundant/Plenum Fan, at least as early as Mar. 15, 2004, 3 pages, CLEANPAK International, Clackmas, Oregon.

Installation Operating and Maintenance Manual, 2003, 12 pages, Greenheck Fan Corp., Schofield, Wisconsin.

DPL Series—Delhi Plenum Fan: Installation and Maintenance Instructions, Nov. 2001, 2 pages, Delhi Industries Inc., Delhi, Ontario, Canada.

AAON worksheet and drawing regarding Borders East Towers job for customer Borders Group, dated Feb. 26, 2001 and Feb. 6, 2001 (2 pages).

AAON order form, estimating worksheet, and facsimile transmission regarding The Commons job, dated Sep. 15, 1998, Sep. 30, 1998 and Jun. 30, 1998 (3 pages).

AAON wiring diagram assignment and verification regarding Farm Show Arena job, Apr. 1, 2002 (1 page).

AAON worksheet and drawing regarding Harrison Hills job, both dated Feb. 26, 2002 (2 pages).

AAON RL Feature Master Number sheet, dated Oct. 17, 2001 (1 page).

Mammouth Selection Guide for Custom Penthouse (200-410 Tons Cooling-only VAV configurations, 1992 (14 pages).

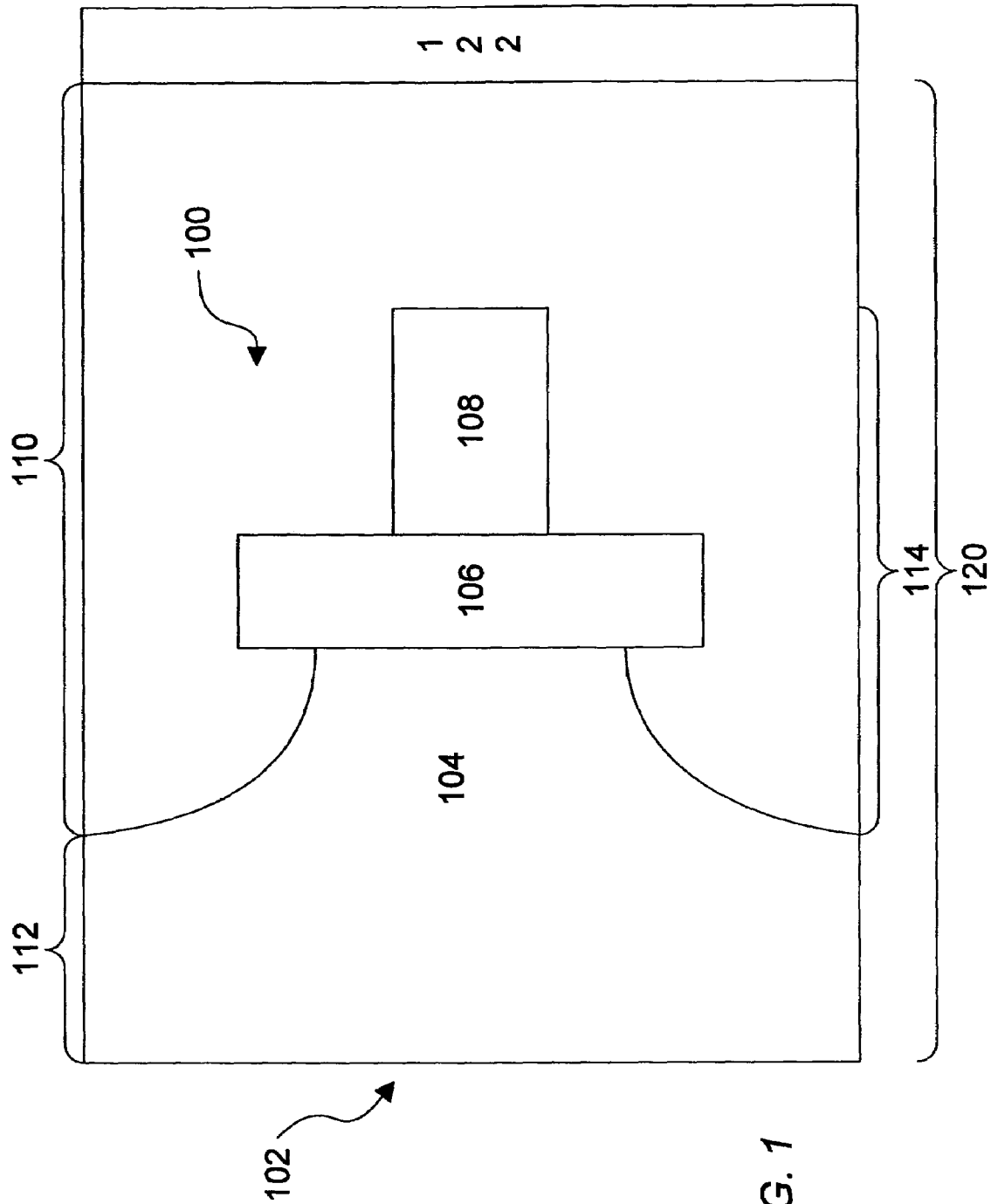
\* cited by examiner

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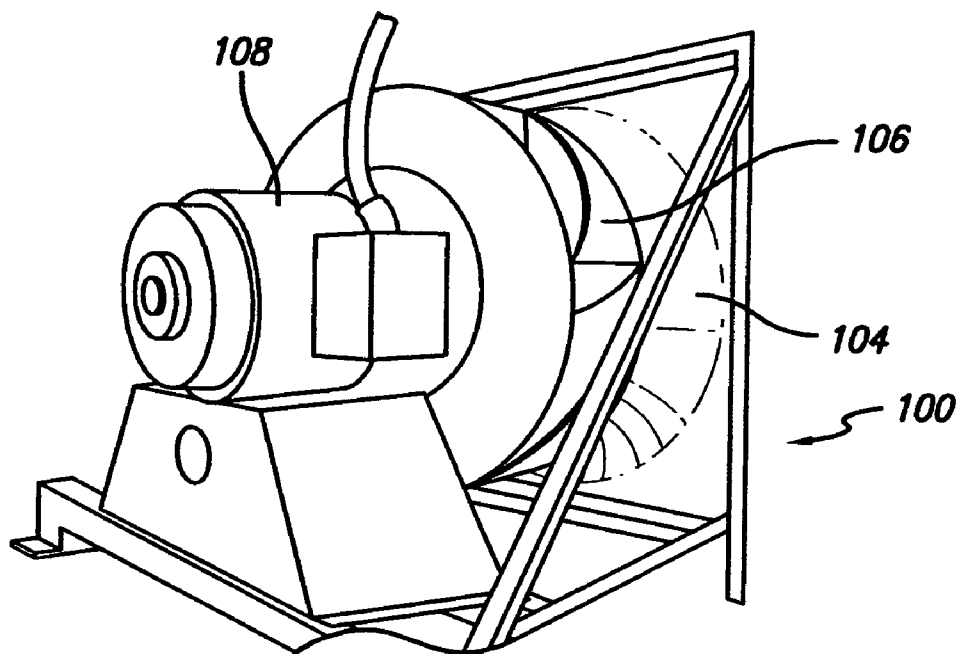


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*FIG. 2*

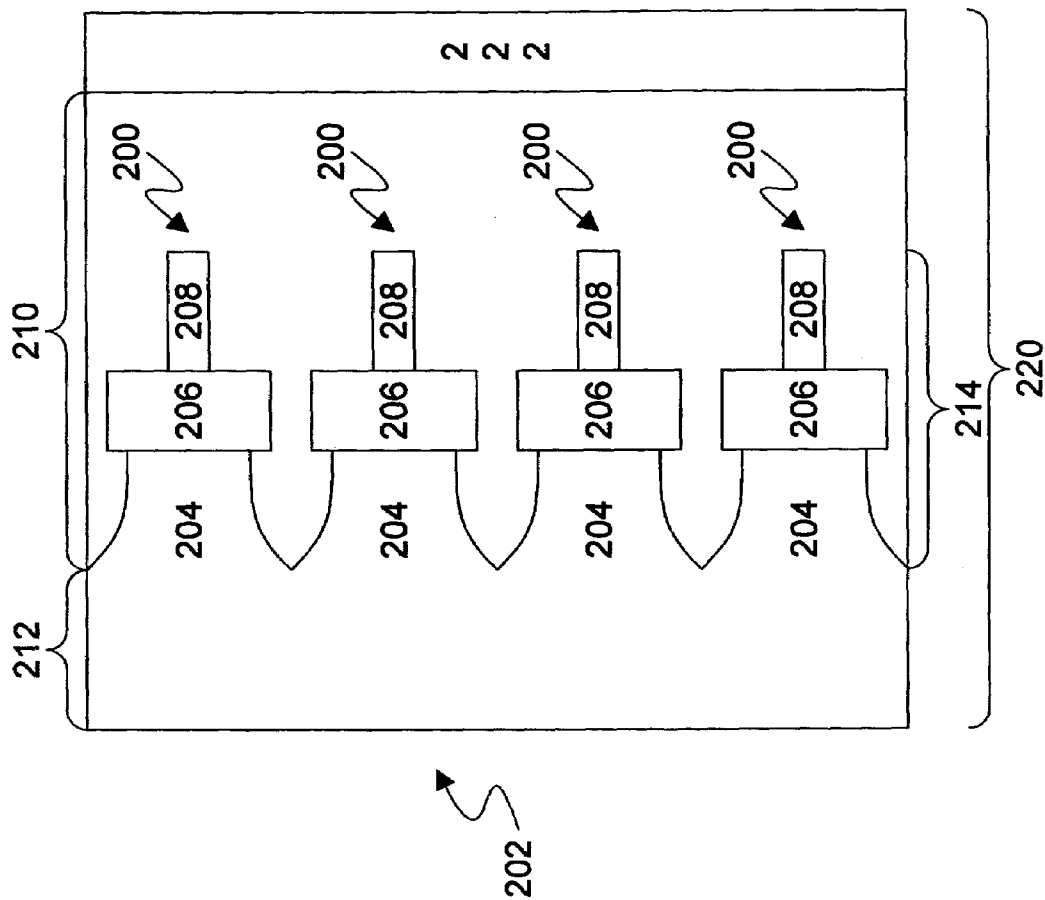


FIG. 3

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**FIG. 4**

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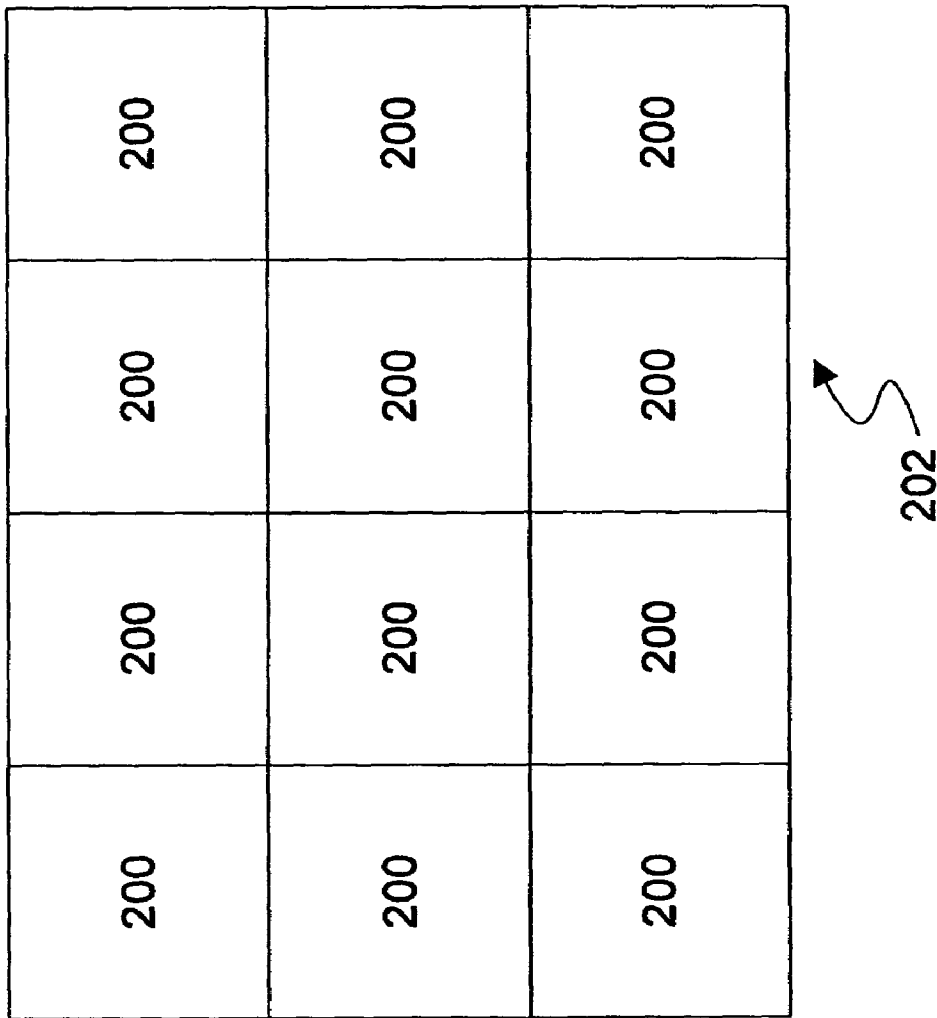
FIG. 5

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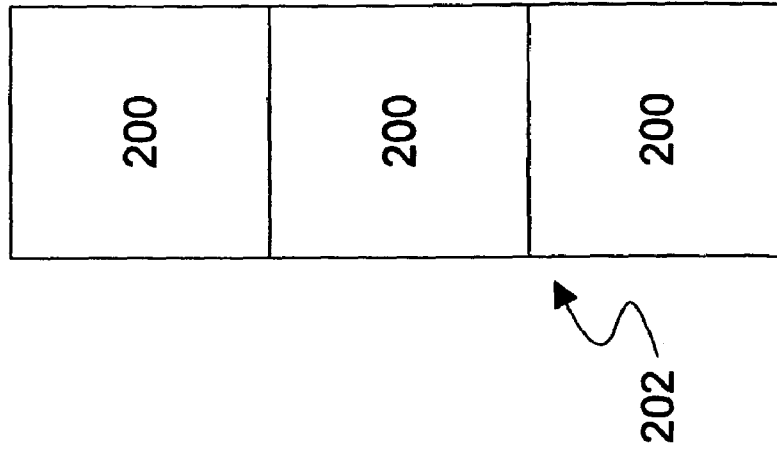
**FIG. 6**

**U.S. Patent**

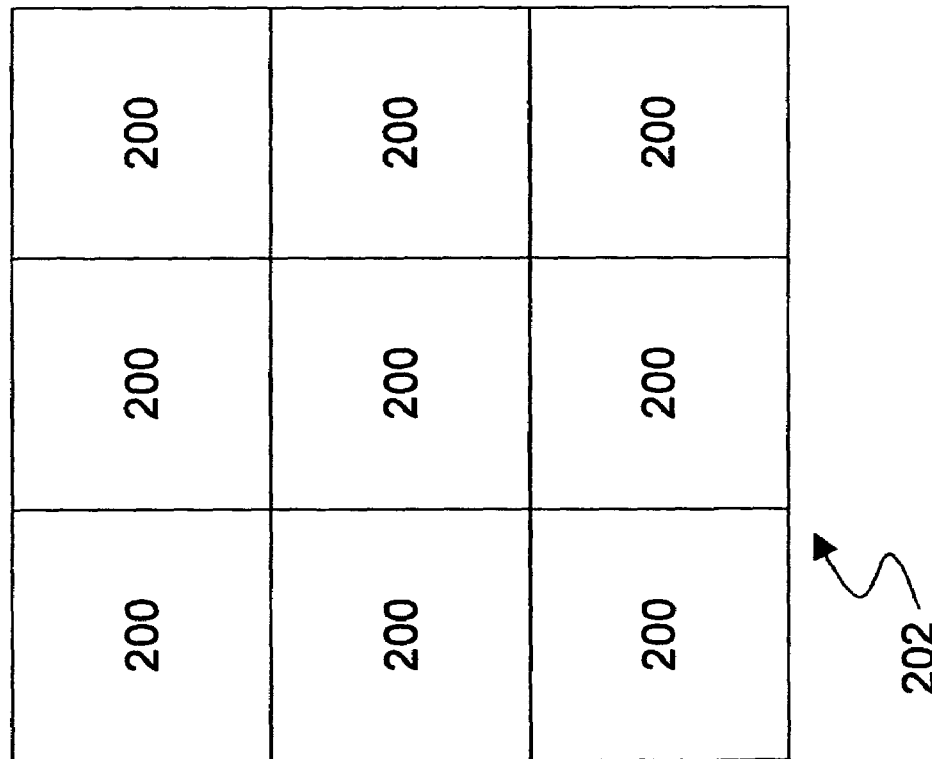
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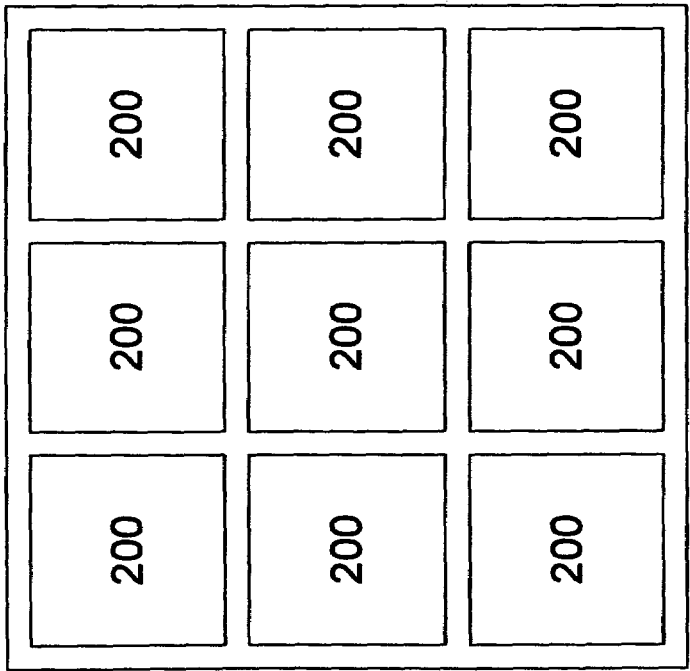


**FIG. 8**



**FIG. 7**





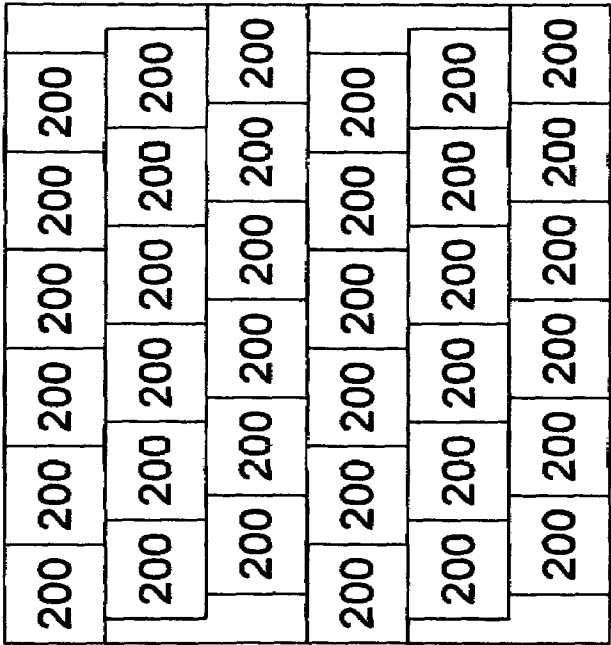
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FIG. 9

200	200	200	200	200	200
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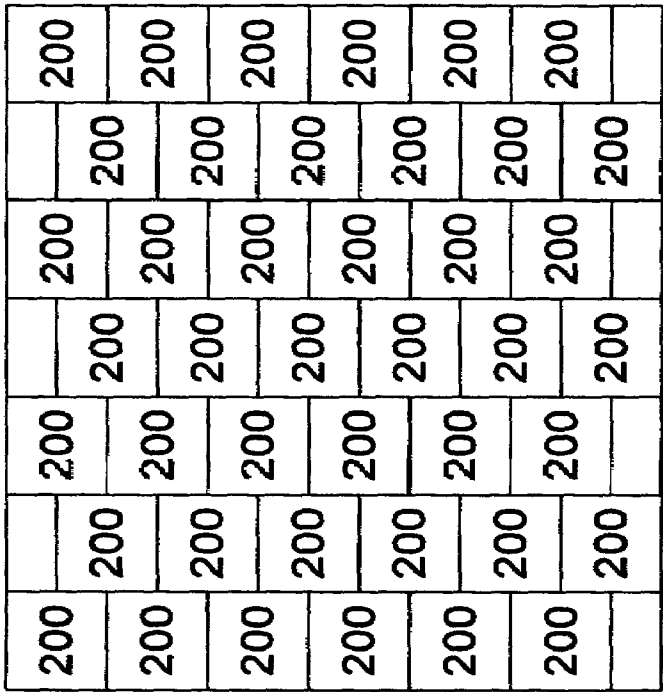
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FIG. 10



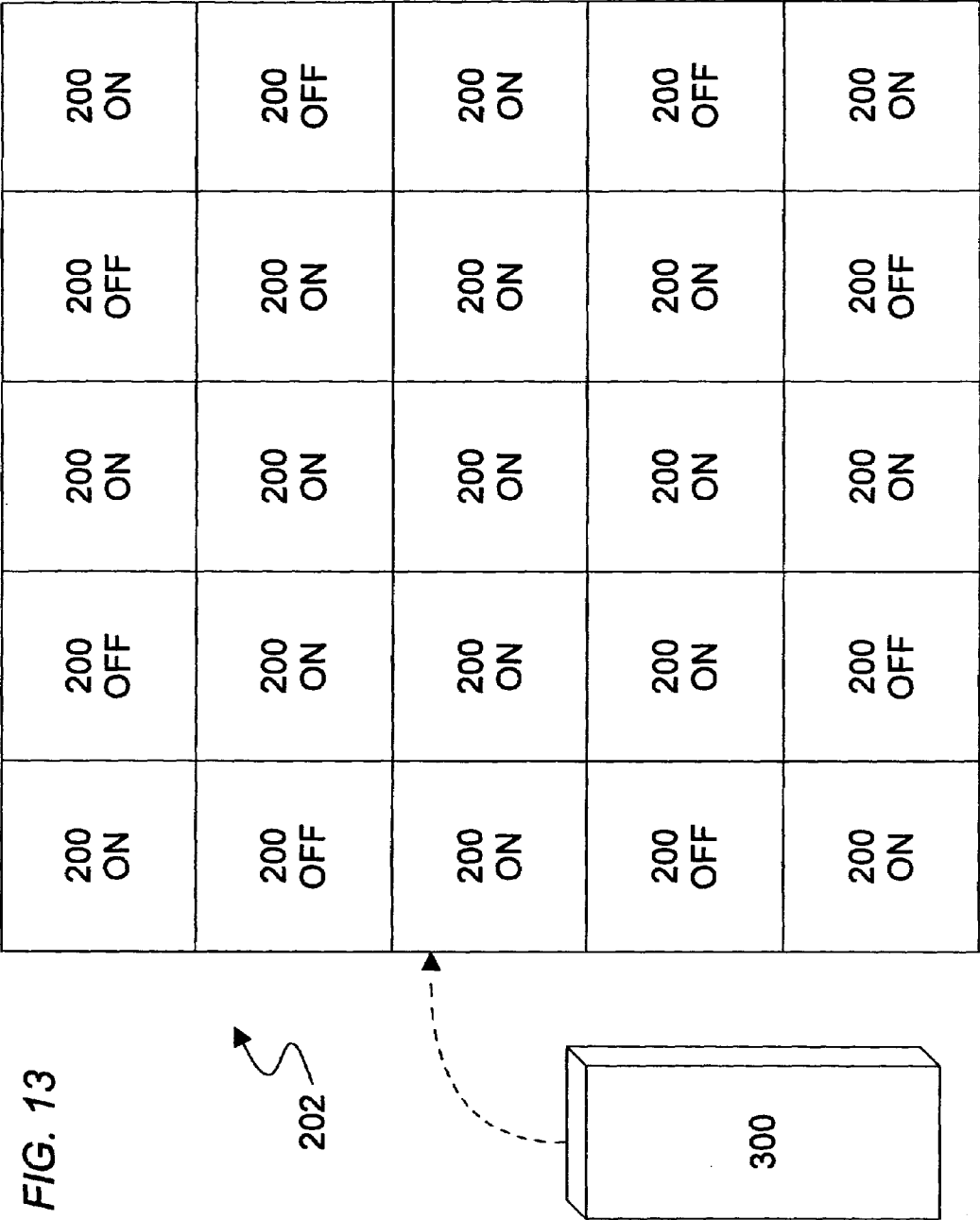
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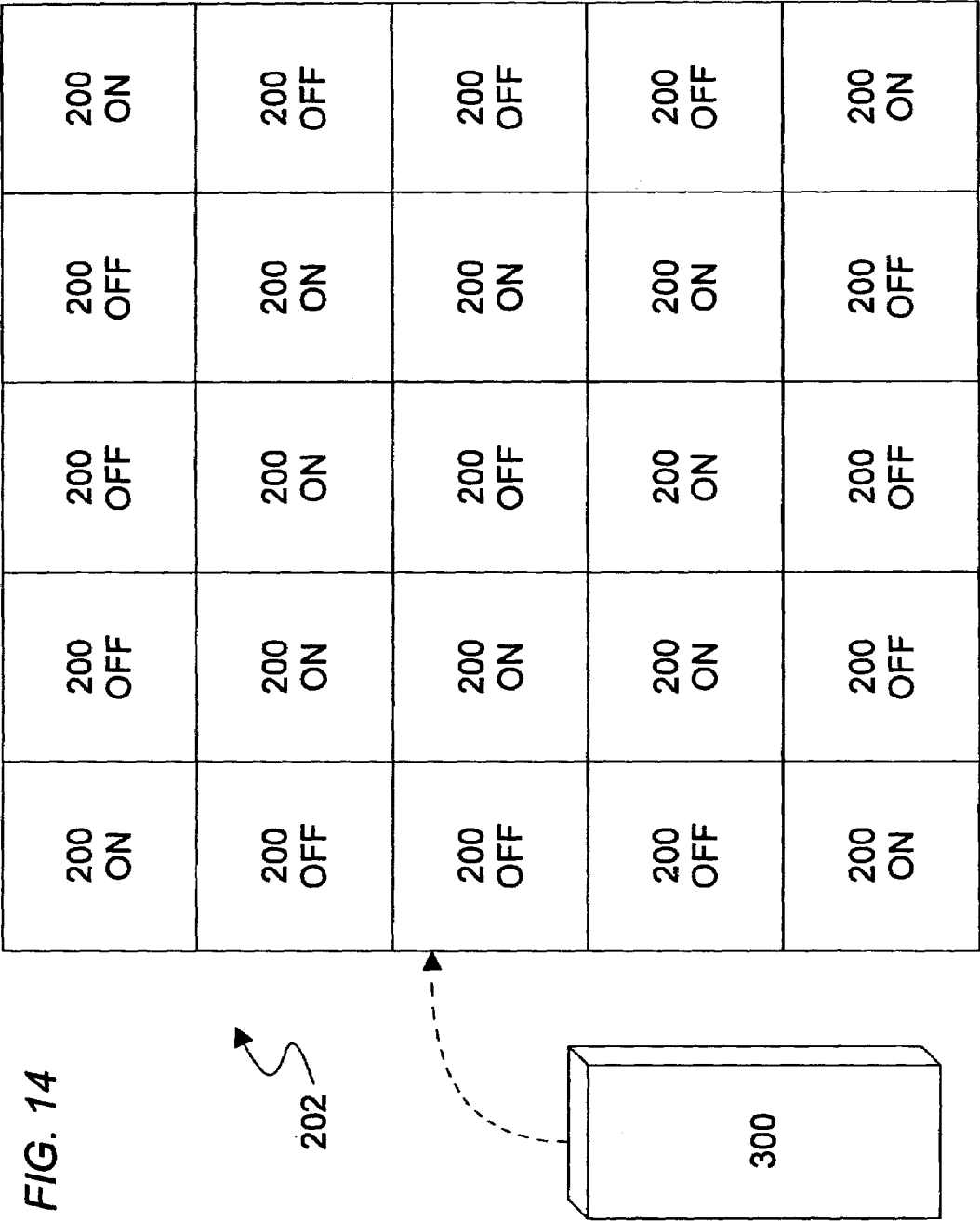
FIG. 11



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FIG. 12





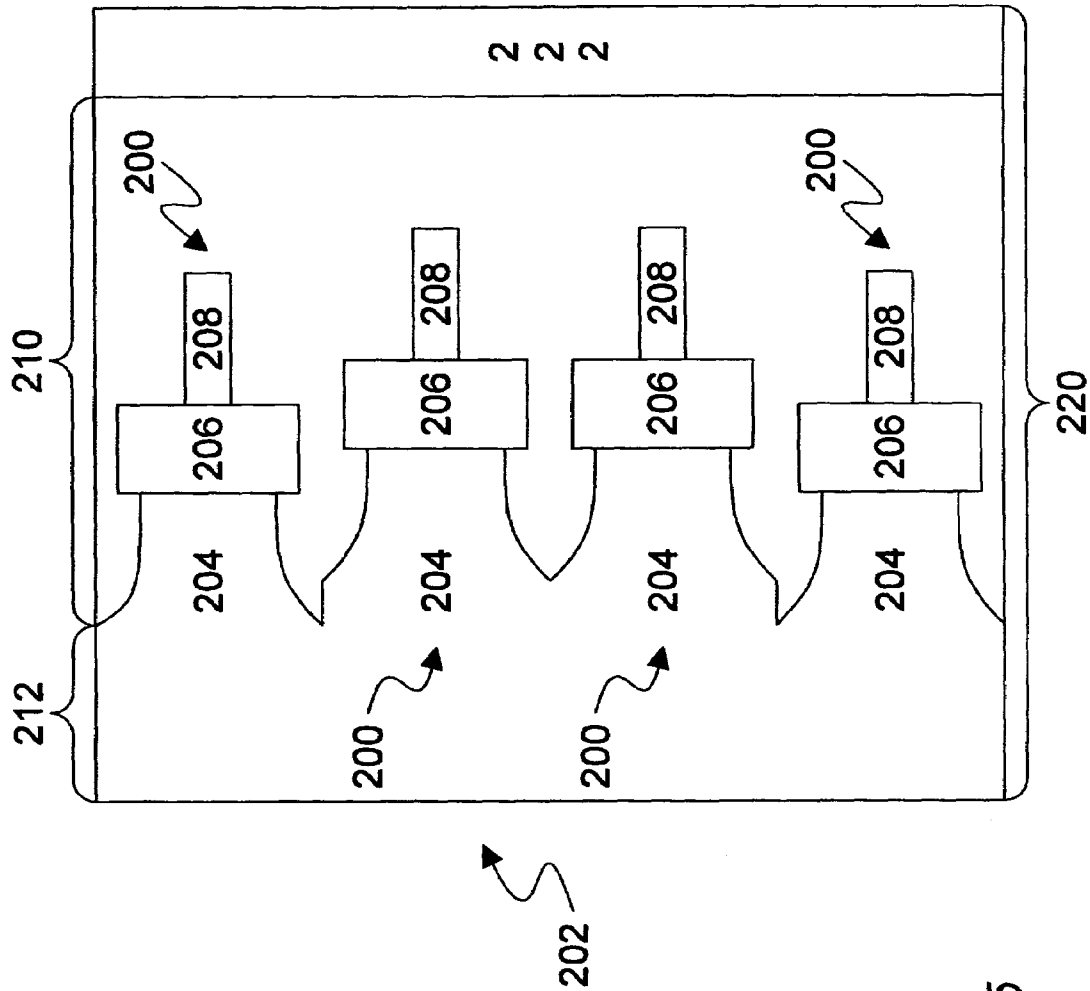


FIG. 15

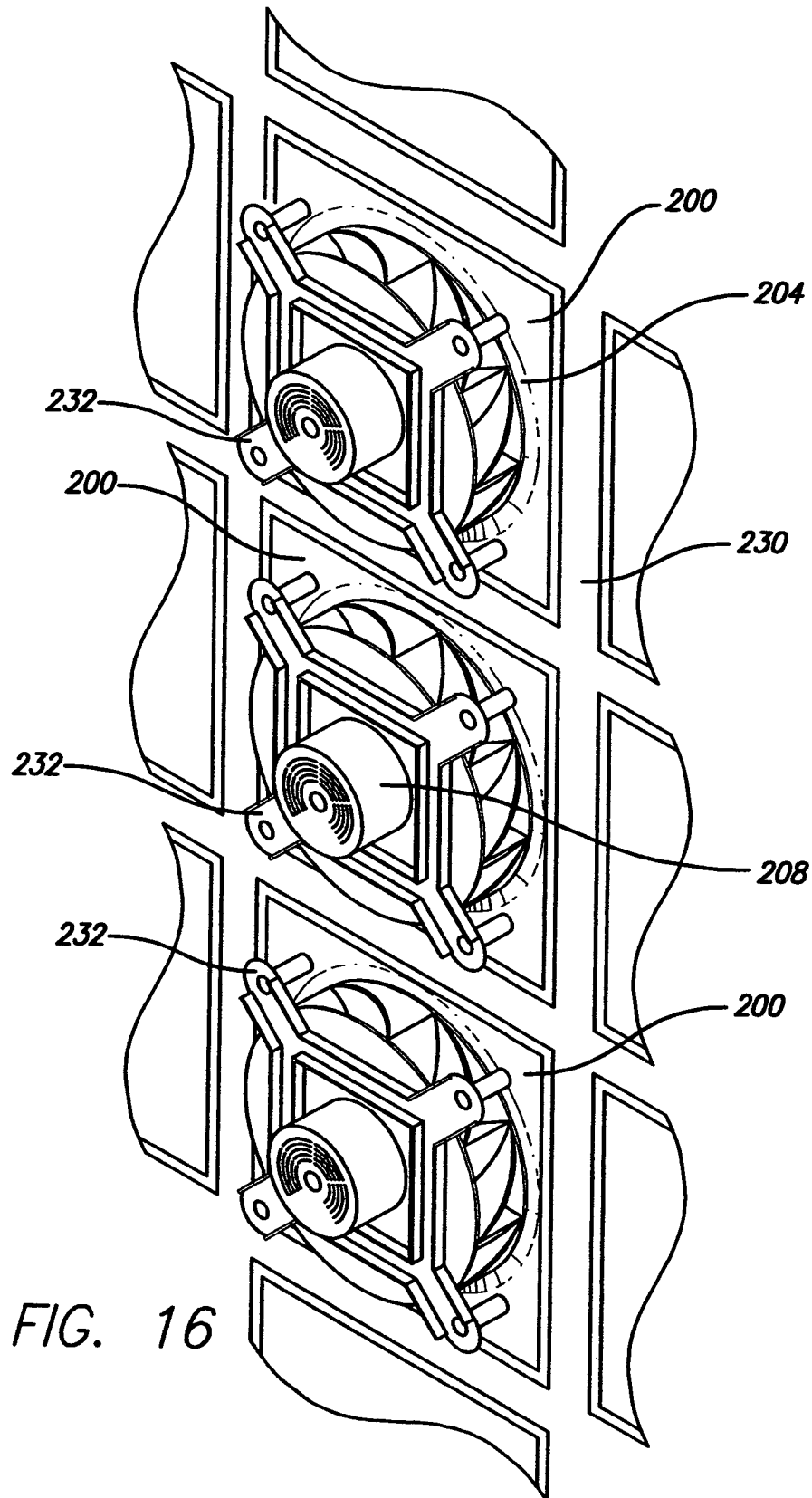


FIG. 16

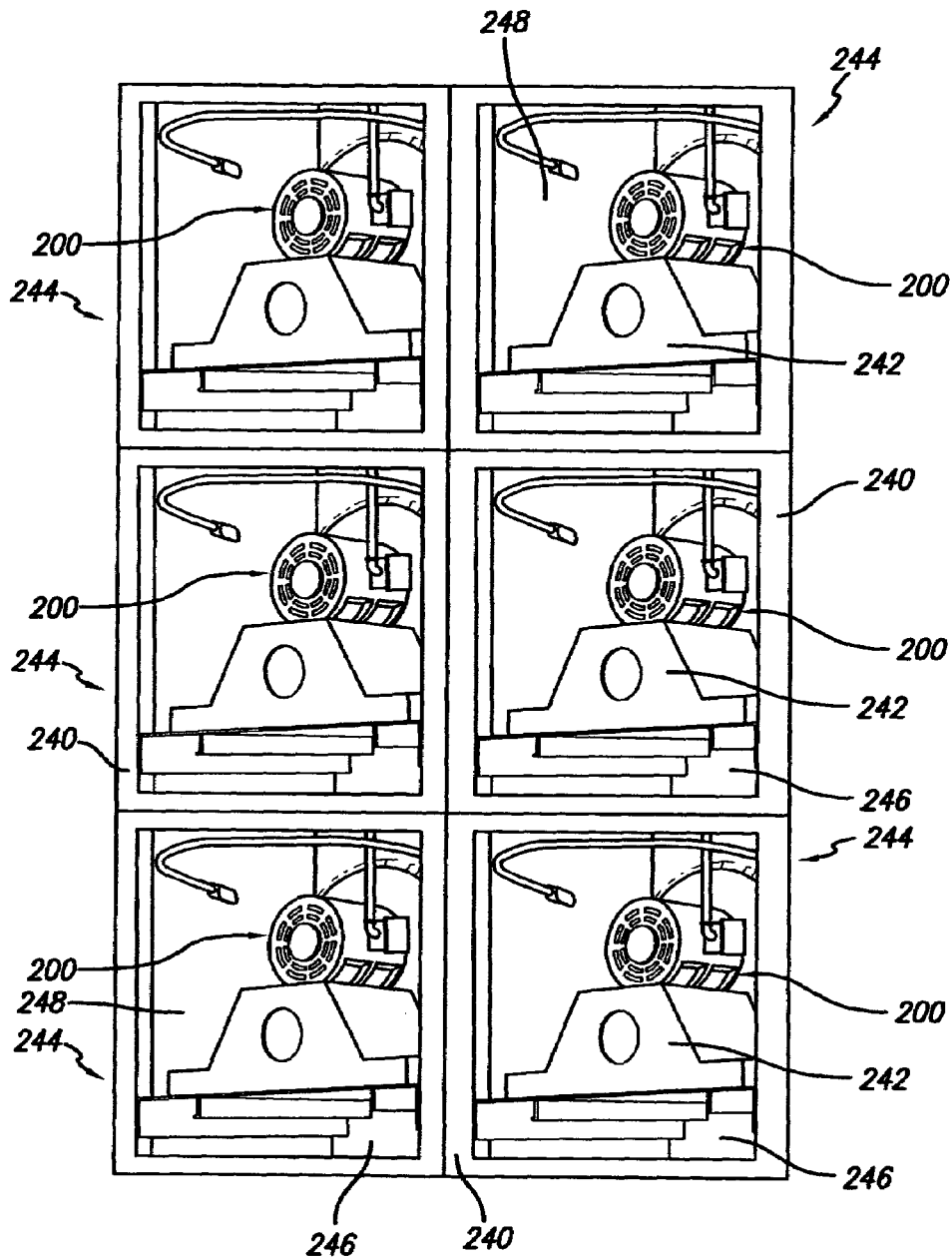


FIG. 17

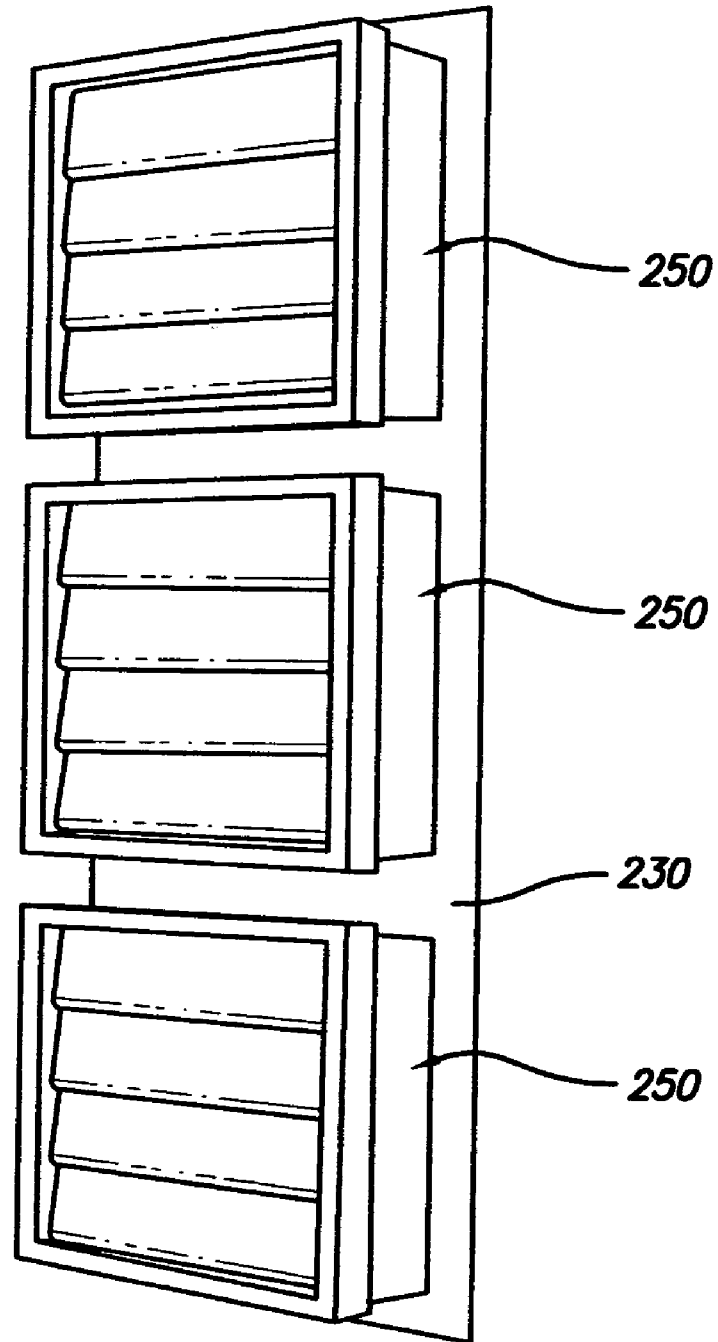


FIG. 18



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## FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS

The present application is a nonprovisional application claiming the benefit under 35 USC Section 119(e) of U.S. Provisional Patent Application Ser. No. 60/456,413, filed Mar. 20, 2003, and entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS. The present application is a continuation-in-part application of PCT Patent Application Serial Number PCT/US2004/008578, filed Mar. 19, 2004, and entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS. The present application is a nonprovisional application claiming the benefit under 35 USC Section 119(e) of U.S. Provisional Patent Application Ser. No. 60/554,702, filed Mar. 20, 2004, and entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS. The present application is based on and claims priority from these applications, the disclosures of which are hereby expressly incorporated herein by reference.

## BACKGROUND OF INVENTION

The present invention is directed to a fan array fan section utilized in an air-handling system.

Air-handling systems (also referred to as an air handler) have traditionally been used to condition buildings or rooms (hereinafter referred to as "structures"). An air-handling system is defined as a system that includes components designed to work together in order to condition air as part of the primary system for ventilation of structures. The air-handling system may contain components such as cooling coils, heating coils, filters, humidifiers, fans, sound attenuators, controls, and other devices functioning to meet the needs of the structures. The air-handling system may be manufactured in a factory and brought to the structure to be installed or it may be built on site using the necessary devices to meet the functioning needs of the structure. The air-handling compartment **102** of the air-handling system includes the inlet plenum **112** prior to the fan inlet cone **104** and the discharge plenum **110**. Within the air-handling compartment **102** is situated the fan unit **100** (shown in FIGS. **1** and **2** as an inlet cone **104**, a fan **106**, and a motor **108**), fan frame, and any appurtenance associated with the function of the fan (e.g. dampers, controls, settling means, and associated cabinetry). Within the fan **106** is a fan wheel (not shown) having at least one blade. The fan wheel has a fan wheel diameter that is measured from one side of the outer periphery of the fan wheel to the opposite side of the outer periphery of the fan wheel. The dimensions of the handling compartment **102** such as height, width, and airway length are determined by consulting fan manufacturers data for the type of fan selected.

FIG. **1** shows an exemplary prior art air-handling system having a single fan unit **100** housed in an air-handling compartment **102**. For exemplary purposes, the fan unit **100** is shown having an inlet cone **104**, a fan **106**, and a motor **108**. Larger structures, structures requiring greater air volume, or structures requiring higher or lower temperatures have generally needed a larger fan unit **100** and a generally correspondingly larger air-handling compartment **102**.

As shown in FIG. **1**, an air-handling compartment **102** is substantially divided into a discharge plenum **110** and an inlet plenum **112**. The combined discharge plenum **110** and the inlet plenum **112** can be referred to as the airway path **120**. The fan unit **100** may be situated in the discharge plenum **110** as shown, the inlet plenum **112**, or partially within the inlet plenum **112** and partially within the dis-

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charge plenum **110**. The portion of the airway path **120** in which the fan unit **100** is positioned may be generically referred to as the "fan section" (indicated by reference numeral **114**). The size of the inlet cone **104**, the size of the fan **106**, the size the motor **108**, and the size of the fan frame (not shown) at least partially determine the length of the airway path **120**. Filter banks **122** and/or cooling coils (not shown) may be added to the system either upstream or downstream of the fan units **100**.

For example, a first exemplary structure requiring 50,000 cubic feet per minute of air flow at six (6) inches water gage pressure would generally require a prior art air-handling compartment **102** large enough to house a 55 inch impeller, a 100 horsepower motor, and supporting framework. The prior art air-handling compartment **102**, in turn would be approximately 92 inches high by 114 to 147 inches wide and 106 to 112 inches long. The minimum length of the air-handling compartment **102** and/or airway path **120** would be dictated by published manufacturers data for a given fan type, motor size, and application. Prior art cabinet sizing guides show exemplary rules for configuring an air-handling compartment **102**. These rules are based on optimization, regulations, and experimentation.

For example, a second exemplary structure includes a recirculation air handler used in semiconductor and pharmaceutical clean rooms requiring 26,000 cubic feet per minute at two (2) inches water gage pressure. This structure would generally require a prior art air-handling system with a air-handling compartment **102** large enough to house a 44 inch impeller, a 25 horsepower motor, and supporting framework. The prior art air-handling compartment **102**, in turn would be approximately 78 inches high by 99 inches wide and 94 to 100 inches long. The minimum length of the air-handling compartment **102** and/or airway path **120** would be dictated by published manufacturers data for a given fan type, motor size and application. Prior art cabinet sizing guides show exemplary rules for configuring an air-handling compartment **102**. These rules are based on optimization, regulations, and experimentation.

These prior art air-handling systems have many problems including the following exemplary problems:

Because real estate (e.g. structure space) is extremely expensive, the larger size of the air-handling compartment **102** is extremely undesirable.

The single fan units **100** are expensive to produce and are generally custom produced for each job.

Single fan units **100** are expensive to operate.

Single fan units **100** are inefficient in that they only have optimal or peak efficiency over a small portion of their operating range.

If a single fan unit **100** breaks down, there is no air conditioning at all.

The low frequency sound of the large fan unit **100** is hard to attenuate.

The high mass and turbulence of the large fan unit **100** can cause undesirable vibration.

Height restrictions have necessitated the use of air-handling systems built with two fan units **100** arranged horizontally adjacent to each other. It should be noted, however, that a good engineering practice is to design air handler cabinets and discharge plenums **110** to be symmetrical to facilitate more uniform air flow across the width and height of the cabinet. Twin fan units **100** have been utilized where there is a height restriction and the unit is designed with a high aspect ratio to accommodate the desired flow rate. As

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shown in the Greenheck "Installation Operating and Maintenance Manual," if side-by-side installation was contemplated, there were specific instructions to arrange the fans such that there was at least one fan wheel diameter spacing between the fan wheels and at least one-half a fan wheel diameter between the fan and the walls or ceilings. The Greenheck reference even specifically states that arrangements "with less spacing will experience performance losses." Normally, the air-handling system and air-handling compartment 102 are designed for a uniform velocity gradient of 500 feet per minute velocity in the direction of air flow. The two fan unit 100 air-handling systems, however, still substantially suffered from the problems of the single unit embodiments. There was no recognition of advantages by increasing the number of fan units 100 from one to two. Further, the two fan unit 100 section exhibits a non-uniform velocity gradient in the region following the fan unit 100 that creates uneven air flow across filters, coils, and sound attenuators.

It should be noted that electrical devices have taken advantage of multiple fan cooling systems. For example, U.S. Pat. No. 6,414,845 to Bonet uses a multiple-fan modular cooling component for installation in multiple component-bay electronic devices. Although some of the advantages realized in the Bonet system would be realized in the present system, there are significant differences. For example, the Bonet system is designed to facilitate electronic component cooling by directing the output from each fan to a specific device or area. The Bonet system would not work to direct air flow to all devices in the direction of general air flow. Other patents such as U.S. Pat. No. 4,767,262 to Simon and U.S. Pat. No. 6,388,880 to El-Ghobashy et al. teach fan arrays for use with electronics.

Even in the computer and machine industries, however, operating fans in parallel is taught against as not providing the desired results except in low system resistance situations where fans operate in near free delivery. For example, Sunon Group has a web page in which they show two axial fans operating in parallel, but specifically state that if "the parallel fans are applied to the higher system resistance that [an] enclosure has, . . . less increase in flow results with parallel fan operation." Similar examples of teaching against using fans in parallel are found in an article accessible from HighBeam Research's library (<http://statl.highbeam.com>) and an article by Ian McLeod accessible at (<http://www.papstplc.com>).

## BRIEF SUMMARY OF THE INVENTION

The present invention is directed to a fan array fan section in an air-handling system that includes a plurality of fan units arranged in a fan array and positioned within an air-handling compartment. One preferred embodiment may include an array controller programmed to operate the plurality of fan units at peak efficiency. The plurality of fan units may be arranged in a true array configuration, a spaced pattern array configuration, a checker board array configuration, rows slightly offset array configuration, columns slightly offset array configuration, or a staggered array configuration.

The foregoing and other objectives, features, and advantages of the invention will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

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## BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. 1 is a side view of an exemplary prior art air-handling system having a single large fan unit within an air-handling compartment.

FIG. 2 is a perspective view of an exemplary prior art large fan unit.

FIG. 3 is a side view of an exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

FIG. 4 is a plan or elevation view of a 4x6 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

FIG. 5 is a plan or elevation view of a 5x5 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

FIG. 6 is a plan or elevation view of a 3x4 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

FIG. 7 is a plan or elevation view of a 3x3 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

FIG. 8 is a plan or elevation view of a 3x1 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

FIG. 9 is a plan or elevation view of an alternative exemplary fan array fan section in an air-handling system of the present invention in which a plurality of small fan units are arranged in a spaced pattern array within an air-handling compartment.

FIG. 10 is a plan or elevation view of an alternative exemplary fan array fan section in an air-handling system of the present invention in which a plurality of small fan units are arranged in a checker board array within an air-handling compartment.

FIG. 11 is a plan or elevation view of an alternative exemplary fan array fan section in an air-handling system of the present invention in which a plurality of small fan units are arranged in rows slightly offset array within an air-handling compartment.

FIG. 12 is a plan or elevation view of an alternative exemplary fan array fan section in an air-handling system of the present invention in which a plurality of small fan units are arranged in columns slightly offset array within an air-handling compartment.

FIG. 13 is a plan or elevation view of a 5x5 exemplary fan array fan section in an air-handling system of the present invention running at 52% capacity by turning a portion of the fans on and a portion of the fans off.

FIG. 14 is a plan or elevation view of a 5x5 exemplary fan array fan section in an air-handling system of the present invention running at 32% capacity by turning a portion of the fans on and a portion of the fans off.

FIG. 15 is a side view of an alternative exemplary fan array fan section in an air-handling system of the present invention having a plurality of staggered small fan units within an air-handling compartment.

FIG. 16 is a perspective view of an exemplary fan array using a grid system into which fan units are mounted.

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FIG. 17 is a perspective view of an exemplary fan array using a grid system or modular units each of which includes a fan units mounted within its own fan unit chamber.

FIG. 18 is a perspective view of an exemplary array of dampeners that may be positioned either in front of or behind the fan units.

#### DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to a fan array fan section in an air-handling system. As shown in FIGS. 3–12, the fan array fan section in the air-handling system uses a plurality of individual single fan units 200. In one preferred embodiment, the fan units 200 are arranged in a true array (FIGS. 4–8), but alternative embodiments may include, for example, alternative arrangements such as in a spaced pattern (FIG. 9), a checker board (FIG. 10), rows slightly offset (FIG. 11), or columns slightly offset (FIG. 12). As the present invention could be implemented with true arrays and/or alternative arrays, the term “array” is meant to be comprehensive.

The fan units 200 in the fan array of the present invention may be spaced as little as 20% of a fan wheel diameter. Optimum operating conditions for a closely arranged array may be found at distances as low as 30% to 60% of a fan wheel diameter. By closely spacing the fan units 200, more air may be moved in a smaller space. For example, if the fan wheels of the fan units 200 have a 20 inch fan wheel diameter, only a 4 inch space (20%) is needed between the outer periphery of one fan wheel and the outer periphery of the adjacent fan wheel (or a 2 inch space between the outer periphery of a fan wheel and an the adjacent wall or ceiling).

By using smaller fan units 200 it is possible to support the fan units 200 with less intrusive structure (fan frame). This can be compared to the large fan frame that supports prior art fan units 100 and functions as a base. This large fan frame must be large and sturdy enough to support the entire weight of the prior art fan units 100. Because of their size and position, the known fan frames cause interference with air flow. In the preferred embodiment, therefore, the fan units 200 of the fan array may be supported by a frame that supports the motors 108 with a minimum restriction to air flow.

As mentioned in the Background, others have tried using side-by-side installation of two fan units 100 arranged horizontally adjacent to each other within an air-handling system. As is also mentioned in the Background, fan arrays have been used in electronic and computer assemblies. However, in the air-handling system industry, it has always been held that there must be significant spacing between the horizontally arranged fan wheels and that arrangements with less spacing will experience performance losses. A single large fan moves all the air in a cabinet. Using two of the same or slightly smaller fans caused the air produced by one fan to interfere with the air produced by the other fan. To alleviate the interference problem, the fans had to be spaced within certain guidelines—generally providing a clear space between the fans of a distance of at least one wheel diameter (and a half a wheel diameter to an adjacent wall). Applying this logic, it would not have made sense to add more fans. And even if additional fans had been added, the spacing would have continued to be at least one wheel diameter between fans. Further, in the air-handling system industry, vertically stacking fan units would have been unthinkable

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because the means for securing the fan units would not have been conducive to such stacking (they are designed to be positioned on the floor only).

It should be noted that the plenum fan is the preferred fan unit 200 of the present invention. In particular, the APF-121, APF-141, APF-161, and APF-181 plenum fans (particularly the fan wheel and the fan cone) produced by Twin City Fan Companies, Ltd. of Minneapolis, Minn., U.S. has been found to work well. The reason that plenum fans work best is that they do not produce points of high velocity such as those produced by axial fans and housed centrifugal fans and large plenum fans. Alternative embodiments use known fan units or fan units yet to be developed that will not produce high velocity gradients in the direction of air flow. Still other embodiments, albeit less efficient, use fan units such as axial fans and/or centrifugal housed fans that have points of high velocity in the direction of air flow.

In the preferred embodiment, each of the fan units 200 in the fan array fan section in the air-handling system is controlled by an array controller 300 (FIGS. 13 and 14). In one preferred embodiment, the array controller 300 may be programmed to operate the fan units 200 at peak efficiency. In this peak efficiency embodiment, rather than running all of the fan units 200 at a reduced efficiency, the array controller 300 turns off certain fan units 200 and runs the remaining fan units 200 at peak efficiency. In an alternative embodiment, the fan units 200 could all run at the same power level (e.g. efficiency and/or flow rate) of operation.

Another advantage of the present invention is that the array controller 300 (which may be a variable frequency drive (VFD)) used for controlling fan speed and thus flow rate and pressure, could be sized for the actual brake horsepower of the fan array fan section in the air-handling system. Since efficiency of the fan wall array can be optimized over a wide range of flow rates and pressures, the actual operating power consumed by the fan array is substantially less than the actual operating power consumed by the comparable prior art air-handling systems and the array controller's power could be reduced accordingly. The array controller 300 could be sized to the actual power consumption of the fan array where as the controller (which may have been a variable frequency drive) in a traditional design would be sized to the maximum nameplate rating of the motor per Electrical Code requirements. An example of a prior art fan design supplying 50,000 cubic feet per minute of air at 2.5 inches pressure, would require a 50 horsepower motor and 50 horsepower controller. The new invention will preferably use an array of fourteen 2 horsepower motors and a 30 horsepower array controller 300.

This invention solves many of the problems of the prior art air-handling systems including, but not limited to real estate, reduced production costs, reduced operating expenses, increased efficiency, improved air flow uniformity, redundancy, sound attenuation advantages, and reduced vibration.

#### Controllability

As mentioned, preferably each of the fan units 200 in the fan array fan section in the air-handling system is controlled by an array controller 300 (FIGS. 13 and 14) that may be programmed to operate the fan units 200 at peak efficiency. In this peak efficiency embodiment, rather than running all of the fan units 200 at a reduced efficiency, the array controller 300 is able to turn off certain fan units 200 and run the remaining fan units 200 at peak efficiency. Preferably,



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the array controller **300** is able to control fan units **200** individually, in predetermined groupings, and/or as a group as a whole.

For example, in the 5x5 fan array such as that shown in FIGS. **5**, **13**, and **14**, a person desiring to control the array may select desired air volume, a level of air flow, a pattern of air flow, and/or how many fan units **200** to operate. Turning first to air volume, each fan unit **200** in a 5x5 array contributes 4% of the total air. In variable air volume systems, which is what most structures have, only the number of fan units **200** required to meet the demand would operate. A control system (that may include the array controller **300**) would be used to take fan units **200** on line (an "ON" fan unit **200**) and off line (an "OFF" fan unit **200**) individually. This ability to turn fan units **200** on and off could effectively eliminate the need for a variable frequency drive. Similarly, each fan unit **200** in a 5x5 array uses 4% of the total power and produces 4% of the level of air flow. Using a control system to take fan units **200** on line and off line allows a user to control power usage and/or air flow. The pattern of air flow can also be controlled if that would be desirable. For example, depending on the system it is possible to create a pattern of air flow only around the edges of a cabinet or air only at the top. Finally, individual fan units **200** may be taken on line and off line. This controllability may be advantageous if one or more fan units **200** are not working properly, need to be maintained (e.g. needs general service), and/or need to be replaced. The problematic individual fan units **200** may be taken off line while the remainder of the system remains fully functional. Once the individual fan units **200** are ready for use, they may be brought back on line.

A further advantage to taking fan units **200** on and off line occurs when building or structure control systems require low volumes of air at relatively high pressures. In this case, the fan units **200** could be modulated to produce a stable operating point and eliminate the surge effects that sometimes plague structure owners and maintenance staff. The surge effect is where the system pressure is too high for the fan speed at a given volume and the fan unit **200** has a tendency to go into stall.

Examples of controllability are shown in FIGS. **13** and **14**. In the fan array fan section in the air-handling system shown in FIG. **13**, the array controller **300** alternates "ON" fan units **200** and "OFF" fan units **200** in a first exemplary pattern as shown so that the entire system is set to operate at 52% of the maximum rated air flow but only consumes 32% of full rated power. These numbers are based on exemplary typical fan operations in a structure. FIG. **14** shows the fan array fan section in the air-handling system set to operate at 32% of the maximum rated air flow but only consumes 17% of full rated power. These numbers are based on exemplary typical fan operations in a structure. In this embodiment, the array controller **300** creates a second exemplary pattern of "OFF" fan units **200** and "ON" fan units **200** as shown.

#### Real Estate

The fan array fan section in the air-handling section **220** of the present invention preferably uses (60% to 80%) less real estate than prior art discharge plenums **120** (with the hundred series number being prior art as shown in FIG. **1** and the two hundred series number being the present invention as shown in FIG. **3**) in air-handling systems. Comparing the prior art (FIG. **1**) and the present invention (FIG. **3**) shows a graphical representation of this shortening of the airway path **120**, **220**. There are many reasons that using multiple smaller fan units **200** can reduce the length of the

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airway path **120**, **220**. For example, reducing the size of the fan unit **100**, **200** and motor **108**, **208** reduces the length of the discharge plenum **110**, **210**. Similarly, reducing the size of the inlet cone **104**, **204** reduces the length of the inlet plenum **112**, **212**. The length of the discharge plenum **110**, **210** can also be reduced because air from the fan array fan section in the air-handling system of the present invention is substantially uniform whereas the prior art air-handling system has points of higher air velocity and needs time and space to mix so that the flow is uniform by the time it exits the air-handling compartment **102**, **202**. (This can also be described as the higher static efficiency in that the present invention eliminates the need for settling means downstream from the discharge of a prior art fan system because there is little or no need to transition from high velocity to low velocity.) The fan array fan section in the air-handling system takes in air from the inlet plenum **212** more evenly and efficiently than the prior art air-handling system so that the length of the inlet plenum **112**, **212** may be reduced.

For purposes of comparison, the first exemplary structure set forth in the Background of the Invention (a structure requiring 50,000 cubic feet per minute of air flow at a pressure of six (6) inches water gage) will be used. Using the first exemplary structure, an exemplary embodiment of the present invention could be served by a nominal discharge plenum **210** of 89 inches high by 160 inches wide and 30 to 36 inches long (as compared to 106 to 112 inches long in the prior art embodiments). The discharge plenum **210** would include a 3x4 fan array fan section in the air-handling system such as the one shown in FIG. **6**) having 12 fan units **200**. The space required for each exemplary fan unit **200** would be a rectangular cube of approximately 24 to 30 inches on a side depending on the array configuration. The airway path **220** is 42 to 48 inches (as compared to 88 to 139 inches in the prior art embodiments).

For purposes of comparison, the second exemplary structure set forth in the Background of the Invention (a structure requiring 26,000 cubic feet per minute of air flow at a pressure of two (2) inches water gage) will be used. Using the second exemplary structure, an exemplary embodiment of the present invention could be served by a nominal discharge plenum **210** of 84 inches high by 84 inches wide, and 30 to 36 inches long (as compared to 94 to 100 inches long in the prior art embodiments). The discharge plenum would include a 3x3 fan array fan section in the air-handling system (such as the one shown in FIG. **7**) having 9 fan units **200**. The space required for each exemplary fan unit **200** would be a rectangular cube of approximately 24 to 30 inches on a side depending on the array configuration. The airway path **220** is 42 to 48 inches (as compared to 71 to 95 inches in the prior art embodiments).

#### Reduced Production Costs

It is generally more cost effective to build the fan array fan section in the air-handling system of the present invention as compared to the single fan unit **100** used in prior art air-handling systems. Part of this cost savings may be due to the fact that individual fan units **200** of the fan array can be mass-produced. Part of this cost savings may be due to the fact that it is less expensive to manufacture smaller fan units **200**. Whereas the prior art single fan units **100** were generally custom built for the particular purpose, the present invention could be implemented on a single type of fan unit **200**. In alternative embodiments, there might be several fan units **200** having different sizes and/or powers (both input and output). The different fan units **200** could be used in a single air-handling system or each air-handling system

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would have only one type of fan unit **200**. Even when the smaller fan units **200** are custom made, the cost of producing multiple fan units **200** for a particular project is almost always less than the cost of producing a single large prior art fan unit **100** for the same project. This may be because of the difficulties of producing the larger components and/or the cost of obtaining the larger components necessary for the single large prior art fan unit **100**. This cost savings also extends to the cost of producing a smaller air-handling compartment **202**.

In one preferred embodiment of the invention, the fan units **200** are modular such that the system is “plug and play.” Such modular units may be implemented by including structure for interlocking on the exterior of the fan units **200** themselves. Alternatively, such modular units may be implemented by using separate structure for interlocking the fan units **200**. In still another alternative embodiment, such modular units may be implemented by using a grid system into which the fan units **200** may be placed.

#### Reduced Operating Expenses

The fan array fan section in the air-handling system of the present invention preferably are less expensive to operate than prior art air-handling systems because of greater flexibility of control and fine tuning to the operating requirements of the structure. Also, by using smaller higher speed fan units **200** that require less low frequency noise control and less static resistance to flow.

#### Increased Efficiency

The fan array fan section in the air-handling system of the present invention preferably is more efficient than prior art air-handling systems because each small fan unit **200** can run at peak efficiency. The system could turn individual fan units **200** on and off to prevent inefficient use of particular fan units **200**. It should be noted that an array controller **300** could be used to control the fan units **200**. As set forth above, the array controller **300** turns off certain fan units **200** and runs the remaining fan units **200** at peak efficiency.

#### Redundancy

Multiple fan units **200** add to the redundancy of the system. If a single fan unit **200** breaks down, there will still be cooling. The array controller **300** may take disabled fan units **200** into consideration such that there is no noticeable depreciation in cooling or air flow rate. This feature may also be useful during maintenance as the array controller **300** may turn off fan units **200** that are to be maintained offline with no noticeable depreciation in cooling or air flow rate.

#### Sound Attenuation Advantages

The high frequency sound of the small fan units **200** is easier to attenuate than the low frequency sound of the large fan unit. Because the fan wall has less low frequency sound energy, shorter less costly sound traps are needed to attenuate the higher frequency sound produced by the plurality of small fan units **200** than the low frequency sound produced by the single large fan unit **100**. The plurality of fan units **200** will each operate in a manner such that acoustic waves from each unit will interact to cancel sound at certain frequencies thus creating a quieter operating unit than prior art systems.

#### Reduced Vibration

The multiple fan units **200** of the present invention have smaller wheels with lower mass and create less force due to residual unbalance thus causing less vibration than the large fan unit. The overall vibration of multiple fan units **200** will

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transmit less energy to a structure since individual fans will tend to cancel each other due to slight differences in phase. Each fan unit **200** of the multiple fan units **200** manage a smaller percentage of the total air handling requirement and thus produce less turbulence in the air stream and substantially less vibration.

#### ALTERNATIVE EMBODIMENTS

As mentioned, in one preferred embodiment of the invention, the fan units **200** are modular such that the system is “plug and play.” Such modular units may be implemented by including structure for interlocking on the exterior of the fan units **200** themselves. Alternatively, such modular units may be implemented by using separate structure for interlocking the fan units **200**. In still another alternative embodiment, such modular units may be implemented by using a grid system into which the fan units **200** may be placed.

FIG. **16** shows an embodiment using an exemplary grid system **230** into which the fan units **200** may be placed. In this embodiment the grid may be positioned and/or built within the air-handling compartment **202**. The fan units **200** may then be positioned into the grid openings. One advantage of this configuration is that individual fan units **200** may be easily removed, maintained, and/or replaced. This embodiment uses an exemplary unique motor mount **232** that supports the motor **208** without interfering with air flow therearound. As shown, this exemplary motor mount **232** has a plurality of arms that mount around the fan inlet cone **204**. It should be noted that the dimensions of the grid are meant to be exemplary. The grid may be constructed taking into consideration that the fan units **200** in the present invention may be spaced with as little as 20% of a fan wheel diameter between the fan units **200**.

FIG. **17** shows an embodiment using either a grid system or modular units **240** using separate structure (not shown) for interlocking the fan units **200**. In this exemplary embodiment, each of the fan units **200** are mounted on a more traditional motor mount **242** within its own fan unit chamber **244**. In one preferred embodiment, the fan unit **200** and motor mount **242** are preferably suspended within their own fan unit chamber **244** such that there is an air relief passage **246** therebelow. This air relieve passage **246** tends to improve air flow around the fan units **200**.

The fan unit chambers **244** shown in FIG. **17** may include one or more interior surface made from or lined with an acoustically absorptive material or “insulation surface” **248**. Going against conventional industry wisdom that surfaces cannot be placed in close proximity with the fan units **200**, the present invention places one or more insulation surfaces **248** at least partially around each fan unit **200** without disrupting air flow. The insulation surfaces **248** may include one or more of the sides, top, bottom, front, or back. Exemplary types of insulation include, but are not limited to traditional insulation board (such as that made from inorganic glass fibers (fiberglass) alone or with a factory-applied foil-scrim-kraft (FSK) facing or a factory-applied all service jacket (ASJ)) or alternative insulation such as open cell foam such as that disclosed in U.S. patent application Ser. No. 10/606,435, which is assigned to the assignee of the present invention, and which the disclosure of which is hereby incorporated by reference herein. Together, the insulation surfaces **248** on the fan unit chambers **244** tend to function as a coplanar silencer. Some of the benefits of using the coplanar silencer include (1) no added airway length for splitters, (2) no pressure drop, and/or (3) relatively low cost.

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The acoustic advantages of this and other embodiments make the present invention ideal for use in concert halls, lecture halls, performing arts centers, libraries, hospitals, and other applications that are acoustically sensitive.

Although FIG. 17 shows the discharge plenum 210 positioned within the fan unit chambers 244, alternative embodiments of fan unit chambers 244 could enclose the inlet plenum 212, or at least partially enclose both the inlet plenum 212 and the discharge plenum 210. Still other alternative embodiments of fan unit chambers 244 may have grid or wire surfaces (that increase the safety of the present invention) or be open (that would reduce costs).

FIG. 18 shows an array of dampeners 250 that may be positioned either in front of or behind the fan units 200 to at least partially prevent back drafts. In the shown exemplary embodiment, the dampeners 250 include a plurality of plates, each plate positioned on its own pivot. In the shown exemplary embodiment, the plurality of plates slightly overlap each other. The shown embodiment is constructed such that when air is flowing through the fan units 200, the plates are in the open position and when the air stops, gravity pulls the plates into the closed position. Preferably, each of the dampeners 250 operates independently such that if some of the fan units 200 are ON and some of the fan units 200 are OFF, the dampeners 250 can open or close accordingly. Although shown as a simple mechanical embodiment, alternative embodiments could include structure that is controlled electronically and/or remotely from the dampeners 250.

It should be noted that FIG. 4 shows a 4×6 fan array fan section in the air-handling system having twenty-four fan units 200, FIG. 5 shows a 5×5 fan array fan section in the air-handling system having twenty-five fan units 200, FIG. 6 shows a 3×4 fan array fan section in the air-handling system having twelve fan units 200, FIG. 7 shows a 3×3 fan array fan section in the air-handling system having nine fan units 200, and FIG. 8 shows a 3×1 fan array fan section in the air-handling system having three fan units 200. It should be noted that the array may be of any size or dimension of more than two fan units 200. It should be noted that although the fan units 200 may be arranged in a single plane (as shown in FIG. 3), an alternative array configuration could contain a plurality of fan units 200 that are arranged in a staggered configuration (as shown in FIG. 15) in multiple planes. It should be noted that cooling coils (not shown) could be added to the system either upstream or downstream of the fan units 200. It should be noted that, although shown upstream from the fan units 200, the filter bank 122, 222 could be downstream.

It should be noted that an alternative embodiment would use a horizontally arranged fan array. In other words, the embodiments shown in FIGS. 3–15 could be used horizontally or vertically or in any direction perpendicular to the direction of air flow. For example, if a vertical portion of air duct is functioning as the air-handling compartment 202, the fan array may be arranged horizontally. This embodiment would be particularly practical in an air handling compartment for a return air shaft.

It should be noted that the fan section 214 may be any portion of the airway path 220 in which the fan units 200 are positioned. For example, the fan units 200 may be situated in the discharge plenum 210 (as shown), the inlet plenum 212, or partially within the inlet plenum 212 and partially within the discharge plenum 210. It should also be noted that the air-handling compartment 202 may be a section of air duct.

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The terms and expressions that have been employed in the foregoing specification are used as terms of description and not of limitation, and are not intended to exclude equivalents of the features shown and described or portions of them. The scope of the invention is defined and limited only by the claims that follow.

What is claimed is:

1. A fan array fan section in an air-handling system comprising:

- (a) at least six fan units;
- (b) said at least six fan units arranged in a fan array;
- (c) an air-handling compartment within which said fan array of fan units is positioned; and
- (d) an array controller for controlling said at least six fan units to run at substantially peak efficiency by strategically turning selective ones of said at least six fan units on and off, wherein each fan unit has a peak efficiency operating range outside of which it operates at a reduced efficiency, and wherein said array controller is programmed to operate said at least six fan units at substantially peak efficiency by strategically turning off at least one fan unit operating at reduced efficiency and running the remaining fan units within said peak efficiency operating range.

2. The fan array fan section in an air-handling system of claim 1, wherein said at least six fan units are plenum fans.

3. The fan array fan section in an air-handling system of claim 1, wherein said air-handling compartment has an airway path, said airway path being less than 72 inches.

4. The fan array fan section in an air-handling system of claim 1, wherein said at least six fan units are a plurality of fan units arranged in a fan array configuration selected from the group consisting of:

- (a) a true array configuration;
- (b) a spaced pattern array configuration;
- (c) a checker board array configuration;
- (d) rows slightly offset array configuration;
- (e) columns slightly offset array configuration; and
- (f) a staggered array configuration.

5. The fan array fan section in an air-handling system of claim 1, wherein said at least six fan units include at least two vertically arranged fan units.

6. The fan array fan section in an air-handling system of claim 1, wherein each of said at least six fan units is positioned within a fan unit chamber.

7. The fan array fan section in an air-handling system of claim 1, wherein each of said at least six fan units is suspended within a respective said fan unit chamber such that there is an air relief passage there below.

8. The fan array fan section in an air-handling system of claim 1, wherein each of said at least six fan units is positioned within a fan unit chamber having at least one acoustically absorptive insulation surface.

9. The fan array fan section in an air-handling system of claim 1, wherein each of said at least six fan units are mounted in a grid system.

10. The fan array fan section in an air-handling system of claim 1, wherein each of said at least six fan units has a fan wheel diameter, wherein spacing between said at least six fan units is less than 60% of said fan wheel diameter.

11. The fan array fan section in an air-handling system of claim 1, further comprising an array of backdraft dampeners, each backdraft dampener in line with a respective fan unit.

12. The fan array fan section in an air-handling system of claim 1, said array controller is programmed to operate said



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at least six fan units at peak efficiency for a performance level based on a criteria selected from the following group of criteria:

- (a) air volume;
- (b) level of air flow;
- (c) pattern of air flow; and
- (d) number of fan units to operate.

13. The fan array fan section in an air-handling system of claim 1, said array controller is programmed to operate said at least six fan units to produce a stable operating point and eliminate the surge effects.

14. The fan array fan section in an air-handling system of claim 1, said array controller is programmed to selectively control the speed of each of said at least six fan units to run at substantially peak efficiency.

15. The fan array fan section in an air-handling system of claim 1, said air-handling compartment positionable within a structure such that said air-handling system conditions the air of said structure.

16. A fan array fan section in an air-handling system comprising:

- (a) a plurality of independently controllable fan units, each fan unit comprising an inlet cone, a fan, and a motor;
- (b) said plurality of fan units arranged in a fan array;
- (c) an air-handling compartment within which said fan array of fan units is positioned;
- (d) an array controller for controlling said plurality of fan units to run at substantially peak efficiency by strategically turning selective ones of said plurality of fan units on and off; wherein
- (e) each of said plurality of fan units has a fan wheel diameter, wherein spacing between said plurality of fan units is less than 60% of said fan wheel diameter.

17. The fan array fan section in an air-handling system of claim 16, wherein said plurality of fan units are plenum fans.

18. The fan array fan section in an air-handling system of claim 16, wherein said air-handling compartment has an airway path, said airway path being less than 72 inches.

19. The fan array fan section in an air-handling system of claim 16, wherein said plurality of fan units are a plurality of fan units arranged in a fan array configuration selected from the group consisting of:

- (a) a true array configuration;
- (b) a spaced pattern array configuration;
- (c) a checker board array configuration;
- (d) rows slightly offset array configuration;
- (e) columns slightly offset array configuration; and
- (f) a staggered array configuration.

20. The fan array fan section in an air-handling system of claim 16, wherein said plurality of fan units include at least two vertically arranged fan units.

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21. The fan array fan section in an air-handling system of claim 16, wherein each of said plurality of fan units is positioned within a fan unit chamber.

22. The fan array fan section in an air-handling system of claim 16, wherein each of said plurality of fan units is suspended within a respective said fan unit chamber such that there is an air relief passage therebelow.

23. The fan array fan section in an air-handling system of claim 16, wherein each of said plurality of fan units is positioned within a fan unit chamber having at least one acoustically absorptive insulation surface.

24. The fan array fan section in an air-handling system of claim 16, wherein each of said plurality of fan units is mounted in a grid system.

25. The fan array fan section in an air-handling system of claim 16, further comprising an array of backdraft dampeners, each backdraft dampener in line with a respective fan unit.

26. The fan array fan section in an air-handling system of claim 16, wherein each fan unit has a peak efficiency operating range outside of which it operates at a reduced efficiency, wherein said array controller is programmed to operate said plurality of fan units at substantially peak efficiency by strategically turning off at least one fan unit operating at reduced efficiency and running the remaining fan units within said peak efficiency operating range.

27. The fan array fan section in an air-handling system of claim 16, said array controller is programmed to operate said plurality of fan units at peak efficiency for a performance level based on a criteria selected from the following group of criteria:

- (a) air volume;
- (b) level of air flow;
- (c) pattern of air flow; and
- (d) number of fan units to operate.

28. The fan array fan section in an air-handling system of claim 16, said array controller is programmed to operate said plurality of fan units to produce a stable operating point and eliminate the surge effects.

29. The fan array fan section in an air-handling system of claim 16, said array controller is programmed to selectively control the speed of each of said plurality of fan units to run at substantially peak efficiency.

30. The fan array fan section in an air-handling system of claim 16, said air-handling compartment positionable within a structure such that said air-handling system conditions the air of said structure.

\* \* \* \* \*

PTO/SB/05 (01-04)

Approved for use through 07/31/2006. OMB 0651-0032  
U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

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UTILITY  
PATENT APPLICATION  
TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.

Hunt:FanArr1

First Inventor

Hopkins

Title

FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS

Express Mail Label No.

EU122438309US

## APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO:

Mail Stop Patent Application  
Commissioner for Patents  
P.O. Box 1450  
Alexandria VA 22313-1450

1. ☒ Fee Transmittal Form (e.g., PTO/SB/17) and check  
(Submit an original and a duplicate for fee processing)
2. ☒ Applicant claims small entity status.  
See 37 CFR 1.27.
3. ☒ Specification [Total Pages 25]  
(preferred arrangement set forth below)  
- Descriptive title of the invention  
- Cross Reference to Related Applications  
- Statement Regarding Fed sponsored R & D  
- Reference to sequence listing, a table,  
or a computer program listing appendix  
- Background of the Invention  
- Brief Summary of the Invention  
- Brief Description of the Drawings (if filed)  
- Detailed Description  
- Claim(s)  
- Abstract of the Disclosure
4. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 15]
5. Oath or Declaration [Total Sheets 1]  
a. ☒ Newly executed (original or copy)  
b. ☐ Copy from a prior application (37 CFR 1.63(d))  
(for continuation/divisional with Box 18 completed)  
i. ☐ **DELETION OF INVENTOR(S)**  
Signed statement attached deleting inventor(s)  
name in the prior application, see 37 CFR  
1.63(d)(2) and 1.33(b).
6. ☒ Application Data Sheet. See 37 CFR 1.76

7. ☐ CD-ROM or CD-R in duplicate, large table or  
Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission  
(if applicable, all necessary)  
a. ☐ Computer Readable Form (CRF)  
b. Specification Sequence Listing on:  
i. ☐ CD-ROM or CD-R (2 copies); or  
ii. ☐ Paper  
c. ☐ Statements verifying identity of above copies

## ACCOMPANYING APPLICATION PARTS

9. ☒ Assignment Papers (cover sheet, document(s), and check)
10. ☒ 37 CFR 3.73(b) Statement ☒ Power of  
(when there is an assignee) Attorney
11. ☐ English Translation Document (if applicable)
12. ☒ Information Disclosure ☒ Copies of IDS  
Statement (IDS)/PTO-1449 Citations
13. ☐ Preliminary Amendment (for non US patent  
references)
14. ☒ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15. ☐ Certified Copy of Priority Document(s)  
(if foreign priority is claimed)
16. ☐ Nonpublication Request under 35 U.S.C. 122  
(b)(2)(B)(i). Applicant must attach form PTO/SB/35
17. ☒ Other: Petition to Make Special & Attachments (including  
\$130 check); and Certificate of Express Mail

The present application is a nonprovisional application claiming the benefit under 35 USC Section 119(e) of U.S. Provisional Patent Application Serial Number 60/456,413, filed March 20, 2003, and entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS. The present application is a continuation-in-part application of PCT Patent Application Serial Number \_\_\_\_\_, filed March 19, 2004, and entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS. The present application is a nonprovisional application claiming the benefit under 35 USC Section 119(e) of U.S. Provisional Patent Application Serial Number \_\_\_\_\_, filed March 20, 2004, and entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS.

## 19. CORRESPONDENCE ADDRESS

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Zip Code

Country

Telephone

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Name (Print/Type)

Karen Dana Oster

Registration No. (Attorney/Agent)

37,621

Signature

Date

March 22, 2004

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop Patent Application, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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PTO/SB/17 (10-03)

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**FEE TRANSMITTAL**  
**for FY 2004**

Effective 10/01/2003. Patent fees are subject to annual revision.

☒ Applicant claims small entity status. See 37 CFR 1.27**TOTAL AMOUNT OF PAYMENT** (\$) **385****Complete if Known**

Application Number	
Filing Date	March 22, 2004
First Named Inventor	Hopkins
Examiner Name	
Art Unit	
Attorney Docket No.	Hunt:FanArr1

**METHOD OF PAYMENT (check all that apply)**☒ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None☒ Deposit Account:Deposit  
Account  
Number  
Deposit  
Account  
Name

50-2115

The Director is authorized to: (check all that apply)

☒ Charge fee(s) indicated below ☒ Credit any overpayments☒ Charge any additional fee(s) or any underpayment of fee(s)☐ Charge fee(s) indicated below, except for the filing fee to the above-identified deposit account.**FEE CALCULATION****1. BASIC FILING FEE**

Large Entity Fee Code	Small Entity Fee Code	Fee (\$)	Fee (\$)	Fee Description	Fee Paid
1001	2001	770	385	Utility filing fee	385
1002	2002	340	170	Design filing fee	
1003	2003	530	265	Plant filing fee	
1004	2004	770	385	Reissue filing fee	
1005	2005	160	80	Provisional filing fee	
<b>SUBTOTAL (1)</b>					<b>385</b>

**2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE**

Total Claims	Extra Claims	Fee from below	Fee Paid
Independent Claims	-20** =	X	= 0
Multiple Dependent	-3** =	X	= 0

Large Entity Fee Code	Small Entity Fee Code	Fee (\$)	Fee (\$)	Fee Description
1202	2202	18	9	Claims in excess of 20
1201	2201	86	43	Independent claims in excess of 3
1203	2203	290	145	Multiple dependent claim, if not paid
1204	2204	86	43	** Reissue independent claims over original patent
1205	2205	18	9	** Reissue claims in excess of 20 and over original patent

**SUBTOTAL (2)** (\$) **0**

\*\*or number previously paid, if greater; For Reissues, see above

**FEE CALCULATION (continued)****3. ADDITIONAL FEES**

Large Entity Fee Code	Small Entity Fee Code	Fee (\$)	Fee (\$)	Fee Description	Fee Paid
1051	2051	130	65	Surcharge - late filing fee or oath	
1052	2052	50	25	Surcharge - late provisional filing fee or cover sheet	
1053	2053	130	130	Non-English specification	
1812	2520	2,520	2,520	For filing a request for <i>ex parte</i> reexamination	
1804	920*	920*	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1,840*	1,840*	Requesting publication of SIR after Examiner action	
1251	2251	110	55	Extension for reply within first month	
1252	2252	420	210	Extension for reply within second month	
1253	2253	950	475	Extension for reply within third month	
1254	2254	1,480	740	Extension for reply within fourth month	
1255	2255	2,010	1,005	Extension for reply within fifth month	
1401	2401	330	165	Notice of Appeal	
1402	2402	330	165	Filing a brief in support of an appeal	
1403	2403	290	145	Request for oral hearing	
1451	2451	1,510	1,510	Petition to institute a public use proceeding	
1452	2452	110	55	Petition to revive - unavoidable	
1453	2453	1,330	665	Petition to revive - unintentional	
1501	2501	1,330	665	Utility issue fee (or reissue)	
1502	2502	480	240	Design issue fee	
1503	2503	640	320	Plant issue fee	
1460	2460	130	130	Petitions to the Commissioner	
1807	2807	50	50	Processing fee under 37 CFR 1.17(q)	
1806	2806	180	180	Submission of Information Disclosure Stmt	
8021	28021	40	40	Recording each patent assignment per property (times number of properties)	
1809	2809	770	385	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	2810	770	385	For each additional invention to be examined (37 CFR 1.129(b))	
1801	2801	770	385	Request for Continued Examination (RCE)	
1802	2802	900	900	Request for expedited examination of a design application	

Other fee (specify)

\*Reduced by Basic Filing Fee Paid

**SUBTOTAL (3)** (\$) **0****SUBMITTED BY**

(Complete if applicable)

Name (Print/Type)	Karen Dana Oster	Registration No. (Attorney/Agent)	37,621	Telephone	(503) 810-2560
Signature		Date	March 22, 2004		

**WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.**

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CERTIFICATE UNDER 37 CFR 1.10  
CERTIFICATE OF MAILING BY  
"EXPRESS MAIL"

Express Mail No.: EU122438309US

Date of Deposit: March 22, 2004

I hereby certify that the following documents relating to a New U.S. Utility Patent Application entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS and invented by Hopkins are being deposited with the United States Postal Service, "Express Mail Post Office to Addressee" service under 37 CFR 1.10, on the date indicated above and is addressed to Mail Stop PATENT APPLICATION, Commissioner for Patents, P.O. Box 1450; Alexandria, VA 22313-1450.

- ☒ Utility Patent Application Transmittal Form (1 sheet(s))
- ☒ a return acknowledgement postcard
- ☒ Fee Transmittal Form (in duplicate) and check for \$385 for filing fees
- ☒ Specification (25 pages)
- ☒ Drawings (FIGS. 1- 18)(15 sheets)
- ☒ Oath/Declaration(s)
- ☒ Patent Application Data Sheet
- ☒ Assignment Cover Sheet and Assignment(s) and check for \$40 for assignment fee
- ☒ Power of Attorney(s)
- ☒ 373(b) form ~~(and attached copies of Assignment(s) and POA(s))~~
- ☒ Information Disclosure Statement and attached reference(s)
- ☒ Petition to Make Special & check for \$130
- ☒ this Certificate of Mailing by Express Mail



Karen Dana Oster

## FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS

The present application is a nonprovisional application claiming the benefit under 35 USC Section 119(e) of U.S. Provisional Patent Application Serial Number 5 60/456,413, filed March 20, 2003, and entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS. The present application is a continuation-in-part application of PCT Patent Application Serial Number \_\_\_\_\_, filed March 19, 2004, and entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS. The present application is a nonprovisional application claiming the benefit under 35 USC Section 119(e) of U.S. 10 Provisional Patent Application Serial Number \_\_\_\_\_, filed March 20, 2004, and entitled FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS. The present application is based on and claims priority from these applications, the disclosures of which are hereby expressly incorporated herein by reference.

## BACKGROUND OF INVENTION

The present invention is directed to a fan array fan section utilized in an air-handling system.

Air-handling systems (also referred to as an air handler) have traditionally been used to condition buildings or rooms (hereinafter referred to as "structures"). An air-handling system is defined as a structure that includes components designed to work together in order to condition air as part of the primary system for ventilation of structures. The air-handling system may contain components such as cooling coils, heating coils, filters, humidifiers, fans, sound attenuators, controls, and other devices functioning to meet the needs of the structures. The air-handling system may be manufactured in a factory and brought to the structure to be installed or it may be built on site using the necessary devices to meet the functioning needs of the structure. The air-handling compartment 102 of the air-handling system includes the inlet plenum 112 prior to the fan inlet cone 104 and the discharge plenum 110. Within the air-handling compartment 102 is situated the fan unit 100 (shown in FIGS. 1 and 2 as an inlet cone 104, a fan 106, and a motor 108), fan frame, and any appurtenance associated with the function of the fan (e.g. dampers, controls, settling means, and associated cabinetry). Within the fan 106 is a fan wheel (not shown) having at least one blade. The fan wheel has a fan wheel diameter that is measured from one side of the outer periphery of the fan wheel to the opposite side of the outer periphery of the fan wheel. The dimensions of the handling compartment 102 such as height, width, and airway length are determined by consulting fan manufacturers data for the type of fan selected.

FIG. 1 shows an exemplary prior art air-handling system having a single fan unit 100 housed in an air-handling compartment 102. For exemplary purposes, the fan unit 100 is shown having an inlet cone 104, a fan 106, and a motor 108. Larger structures, structures requiring greater air volume, or structures requiring higher or lower temperatures have generally needed a larger fan unit 100 and a generally correspondingly larger air-handling compartment 102.

As shown in FIG. 1, an air-handling compartment 102 is substantially divided into a discharge plenum 110 and an inlet plenum 112. The combined discharge

plenum 110 and the inlet plenum 112 can be referred to as the airway path 120. The fan unit 100 may be situated in the discharge plenum 110 as shown), the inlet plenum 112, or partially within the inlet plenum 112 and partially within the discharge plenum 110. The portion of the airway path 120 in which the fan unit 100 is positioned may be generically referred to as the "fan section" (indicated by reference numeral 114). The size of the inlet cone 104, the size of the fan 106, the size the motor 108, and the size of the fan frame (not shown) at least partially determine the length of the airway path 120. Filter banks 122 and/or cooling coils (not shown) may be added to the system either upstream or downstream of the fan units 100.

For example, a first exemplary structure requiring 50,000 cubic feet per minute of air flow at six (6) inches water gage pressure would generally require a prior art air-handling compartment 102 large enough to house a 55 inch impeller, a 100 horsepower motor, and supporting framework. The prior art air-handling compartment 102, in turn would be approximately 92 inches high by 114 to 147 inches wide and 106 to 112 inches long. The minimum length of the air-handling compartment 102 and/or airway path 120 would be dictated by published manufacturers data for a given fan type, motor size, and application. Prior art cabinet sizing guides show exemplary rules for configuring an air-handling compartment 102. These rules are based on optimization, regulations, and experimentation.

For example, a second exemplary structure includes a recirculation air handler used in semiconductor and pharmaceutical clean rooms requiring 26,000 cubic feet per minute at two (2) inches water gage pressure. This structure would generally require a prior art air-handling system with a air-handling compartment 102 large enough to house a 44 inch impeller, a 25 horsepower motor, and supporting framework. The prior art air-handling compartment 102, in turn would be approximately 78 inches high by 99 inches wide and 94 to 100 inches long. The minimum length of the air-handling compartment 102 and/or airway path 120 would be dictated by published manufacturers data for a given fan type, motor size and application. Prior art cabinet sizing guides show exemplary rules for configuring an air-handling compartment 102. These rules are based on optimization, regulations, and experimentation.

These prior art air-handling systems have many problems including the following exemplary problems:

- Because real estate (e.g. structure space) is extremely expensive, the larger size of the air-handling compartment 102 is extremely undesirable.
- The single fan units 100 are expensive to produce and are generally custom produced for each job.
- Single fan units 100 are expensive to operate.
- Single fan units 100 are inefficient in that they only have optimal or peak efficiency over a small portion of their operating range.
- If a single fan unit 100 breaks down, there is no air conditioning at all.
- The low frequency sound of the large fan unit 100 is hard to attenuate.
- The high mass and turbulence of the large fan unit 100 can cause undesirable vibration.

Height restrictions have necessitated the use of air-handling systems built with two fan units 100 arranged horizontally adjacent to each other. It should be noted, however, that a good engineering practice is to design air handler cabinets and discharge plenums 110 to be symmetrical to facilitate more uniform air flow across the width and height of the cabinet. Twin fan units 100 have been utilized where there is a height restriction and the unit is designed with a high aspect ratio to accommodate the desired flow rate. As shown in the Greenheck "Installation Operating and Maintenance Manual," if side-by-side installation was contemplated, there were specific instructions to arrange the fans such that there was at least one fan wheel diameter spacing between the fan wheels and at least one-half a fan wheel diameter between the fan and the walls or ceilings. The Greenheck reference even specifically states that arrangements "with less spacing will experience performance losses." Normally, the air-handling system and air-handling compartment 102 are designed for a uniform velocity gradient of 500 feet per minute velocity in the direction of air flow. The two fan unit 100

air-handling systems, however, still substantially suffered from the problems of the single unit embodiments. There was no recognition of advantages by increasing the number of fan units 100 from one to two. Further, the two fan unit 100 section exhibits a non-uniform velocity gradient in the region following the fan unit 100 that creates

5 uneven air flow across filters, coils, and sound attenuators.

It should be noted that electrical devices have taken advantage of multiple fan cooling systems. For example, U.S. Patent No. 6,414,845 to Bonet uses a multiple-fan modular cooling component for installation in multiple component-bay electronic devices. Although some of the advantages realized in the Bonet system would be realized in the present system, there are significant differences. For example, the Bonet system is designed to facilitate electronic component cooling by directing the output from each fan to a specific device or area. The Bonet system would not work to direct air flow to all devices in the direction of general air flow. Other patents such as U.S. Patent No. 4,767,262 to Simon and U.S. Patent No. 6,388,880 to El-Ghobashy et al. teach fan arrays for use with electronics.

Even in the computer and machine industries, however, operating fans in parallel is taught against as not providing the desired results except in low system resistance situations where fans operate in near free delivery. For example, Sunon Group has a web page in which they show two axial fans operating in parallel, but specifically state that if "the parallel fans are applied to the higher system resistance that [an] enclosure has, . . . less increase in flow results with parallel fan operation." Similar examples of teaching against using fans in parallel are found in an article accessible from HighBeam Research's library (<http://stati.highbeam.com>) and an article by Ian McLeod accessible at (<http://www.papstplc.com>).



## BRIEF SUMMARY OF THE INVENTION

The present invention is directed to a fan array fan section in an air-handling system that includes a plurality of fan units arranged in a fan array and positioned within an air-handling compartment. One preferred embodiment may include  
5 an array controller programmed to operate the plurality of fan units at peak efficiency. The plurality of fan units may be arranged in a true array configuration, a spaced pattern array configuration, a checker board array configuration, rows slightly offset array configuration, columns slightly offset array configuration, or a staggered array configuration.

10 The foregoing and other objectives, features, and advantages of the invention will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.



**BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS**

FIG. 1 is a side view of an exemplary prior art air-handling system having a single large fan unit within an air-handling compartment.

FIG. 2 is a perspective view of an exemplary prior art large fan unit.

5 FIG. 3 is a side view of an exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

10 FIG. 4 is a plan or elevation view of a 4x6 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

FIG. 5 is a plan or elevation view of a 5x5 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

15 FIG. 6 is a plan or elevation view of a 3x4 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

FIG. 7 is a plan or elevation view of a 3x3 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

20 FIG. 8 is a plan or elevation view of a 3x1 exemplary fan array fan section in an air-handling system of the present invention having a plurality of small fan units within an air-handling compartment.

25 FIG. 9 is a plan or elevation view of an alternative exemplary fan array fan section in an air-handling system of the present invention in which a plurality of small fan units are arranged in a spaced pattern array within an air-handling compartment.

FIG. 10 is a plan or elevation view of an alternative exemplary fan array fan section in an air-handling system of the present invention in which a plurality of small fan units are arranged in a checker board array within an air-handling compartment.

FIG. 11 is a plan or elevation view of an alternative exemplary fan array fan section in an air-handling system of the present invention in which a plurality of small fan units are arranged in rows slightly offset array within an air-handling compartment.

5                FIG. 12 is a plan or elevation view of an alternative exemplary fan array fan section in an air-handling system of the present invention in which a plurality of small fan units are arranged in columns slightly offset array within an air-handling compartment.

10              FIG. 13 is a plan or elevation view of a 5x5 exemplary fan array fan section in an air-handling system of the present invention running at 52% capacity by turning a portion of the fans on and a portion of the fans off.

FIG. 14 is a plan or elevation view of a 5x5 exemplary fan array fan section in an air-handling system of the present invention running at 32% capacity by turning a portion of the fans on and a portion of the fans off.

15              FIG. 15 is a side view of an alternative exemplary fan array fan section in an air-handling system of the present invention having a plurality of staggered small fan units within an air-handling compartment.

FIG. 16 is a perspective view of an exemplary fan array using a grid system into which fan units are mounted.

20              FIG. 17 is a perspective view of an exemplary fan array using a grid system or modular units each of which includes a fan units mounted within its own fan unit chamber.

FIG. 18 is a perspective view of an exemplary array of dampeners that may be positioned either in front of or behind the fan units.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to a fan array fan section in an air-handling system. As shown in FIGS. 3-12, the fan array fan section in the air-handling system uses a plurality of individual single fan units 200. In one preferred embodiment, the fan units 200 are arranged in a true array (FIGS. 4-8), but alternative embodiments may include, for example, alternative arrangements such as in a spaced pattern (FIG. 9), a checker board (FIG. 10), rows slightly offset (FIG. 11), or columns slightly offset (FIG. 12). As the present invention could be implemented with true arrays and/or alternative arrays, the term "array" is meant to be comprehensive.

The fan units 200 in the fan array of the present invention may be spaced as little as 20% of a fan wheel diameter. Optimum operating conditions for a closely arranged array may be found at distances as low as 30% to 60% of a fan wheel diameter. By closely spacing the fan units 200, more air may be moved in a smaller space. For example, if the fan wheels of the fan units 200 have a 20 inch fan wheel diameter, only a 4 inch space (20%) is needed between the outer periphery of one fan wheel and the outer periphery of the adjacent fan wheel (or a 2 inch space between the outer periphery of a fan wheel and an the adjacent wall or ceiling).

By using smaller fan units 200 it is possible to support the fan units 200 with less intrusive structure (fan frame). This can be compared to the large fan frame that supports prior art fan units 100 and functions as a base. This large fan frame must be large and sturdy enough to support the entire weight of the prior art fan units 100. Because of their size and position, the known fan frames cause interference with air flow. In the preferred embodiment, therefore, the fan units 200 of the fan array may be supported by a frame that supports the motors 108 with a minimum restriction to air flow.

As mentioned in the Background, others have tried using side-by-side installation of two fan units 100 arranged horizontally adjacent to each other within an air-handling system. As is also mentioned in the Background, fan arrays have been used in electronic and computer assemblies. However, in the air-handling system industry, it has always been held that there must be significant spacing between the

horizontally arranged fan wheels and that arrangements with less spacing will experience performance losses. A single large fan moves all the air in a cabinet. Using two of the same or slightly smaller fans caused the air produced by one fan to interfere with the air produced by the other fan. To alleviate the interference problem, the fans  
5 had to be spaced within certain guidelines – generally providing a clear space between the fans of a distance of at least one wheel diameter (and a half a wheel diameter to an adjacent wall). Applying this logic, it would not have made sense to add more fans. And even if additional fans had been added, the spacing would have continued to be at least one wheel diameter between fans. Further, in the air-handling system industry,  
10 vertically stacking fan units would have been unthinkable because the means for securing the fan units would not have been conducive to such stacking (they are designed to be positioned on the floor only).

It should be noted that the plenum fan is the preferred fan unit 200 of the present invention. In particular, the APF-121, APF-141, APF-161, and APF-181 plenum  
15 fans (particularly the fan wheel and the fan cone) produced by Twin City Fan Companies, Ltd. of Minneapolis, Minnesota, U.S. has been found to work well. The reason that plenum fans work best is that they do not produce points of high velocity such as those produced by axial fans and housed centrifugal fans and large plenum fans. Alternative embodiments use known fan units or fan units yet to be developed  
20 that will not produce high velocity gradients in the direction of air flow. Still other embodiments, albeit less efficient, use fan units such as axial fans and/or centrifugal housed fans that have points of high velocity in the direction of air flow.

In the preferred embodiment, each of the fan units 200 in the fan array fan section in the air-handling system is controlled by an array controller 300 (FIGS. 13 and  
25 14). In one preferred embodiment, the array controller 300 may be programmed to operate the fan units 200 at peak efficiency. In this peak efficiency embodiment, rather than running all of the fan units 200 at a reduced efficiency, the array controller 300 turns off certain fan units 200 and runs the remaining fan units 200 at peak efficiency. In an alternative embodiment, the fan units 200 could all run at the same power level  
30 (e.g. efficiency and/or flow rate) of operation.

Another advantage of the present invention is that the array controller 300 (which may be a variable frequency drive (VFD)) used for controlling fan speed and thus flow rate and pressure, could be sized for the actual brake horsepower of the fan array fan section in the air-handling system. Since efficiency of the fan wall array can be optimized over a wide range of flow rates and pressures, the actual operating power consumed by the fan array is substantially less than the actual operating power consumed by the comparable prior art air-handling systems and the array controller's power could be reduced accordingly. The array controller 300 could be sized to the actual power consumption of the fan array where as the controller (which may have been a variable frequency drive) in a traditional design would be sized to the maximum nameplate rating of the motor per Electrical Code requirements. An example of a prior art fan design supplying 50,000 cubic feet per minute of air at 2.5 inches pressure, would require a 50 horsepower motor and 50 horsepower controller. The new invention will preferably use an array of fourteen 2 horsepower motors and a 30 horsepower array controller 300.

This invention solves many of the problems of the prior art air-handling systems including, but not limited to real estate, reduced production costs, reduced operating expenses, increased efficiency, improved air flow uniformity, redundancy, sound attenuation advantages, and reduced vibration.

#### Controllability

As mentioned, preferably each of the fan units 200 in the fan array fan section in the air-handling system is controlled by an array controller 300 (FIGS. 13 and 14) that may be programmed to operate the fan units 200 at peak efficiency. In this peak efficiency embodiment, rather than running all of the fan units 200 at a reduced efficiency, the array controller 300 is able to turn off certain fan units 200 and run the remaining fan units 200 at peak efficiency. Preferably, the array controller 300 is able to control fan units 200 individually, in predetermined groupings, and/or as a group as a whole.

For example, in the 5x5 fan array such as that shown in FIGS. 5, 13, and 14, a person desiring to control the array may select desired air volume, a level of air flow, a pattern of air flow, and/or how many fan units 200 to operate. Turning first to air volume, each fan unit 200 in a 5x5 array contributes 4% of the total air. In variable air volume systems, which is what most structures have, only the number of fan units 200 required to meet the demand would operate. A control system (that may include the array controller 300) would be used to take fan units 200 on line (an "ON" fan unit 200) and off line (an "OFF" fan unit 200) individually. This ability to turn fan units 200 on and off could effectively eliminate the need for a variable frequency drive. Similarly, each fan unit 200 in a 5x5 array uses 4% of the total power and produces 4% of the level of air flow. Using a control system to take fan units 200 on line and off line allows a user to control power usage and/or air flow. The pattern of air flow can also be controlled if that would be desirable. For example, depending on the system it is possible to create a pattern of air flow only around the edges of a cabinet or air only at the top. Finally, individual fan units 200 may be taken on line and off line. This controllability may be advantageous if one or more fan units 200 are not working properly, need to be maintained (e.g. needs general service), and/or need to be replaced. The problematic individual fan units 200 may be taken off line while the remainder of the system remains fully functional. Once the individual fan units 200 are ready for use, they may be brought back on line.

A further advantage to taking fan units 200 on and off line occurs when building or structure control systems require low volumes of air at relatively high pressures. In this case, the fan units 200 could be modulated to produce a stable operating point and eliminate the surge effects that sometimes plague structure owners and maintenance staff. The surge effect is where the system pressure is too high for the fan speed at a given volume and the fan unit 200 has a tendency to go into stall.

Examples of controllability are shown in FIGS. 13 and 14. In the fan array fan section in the air-handling system shown in FIG. 13, the array controller 300 alternates "ON" fan units 200 and "OFF" fan units 200 in a first exemplary pattern as shown so that the entire system is set to operate at 52% of the maximum rated air flow

but only consumes 32% of full rated power. These numbers are based on exemplary typical fan operations in a structure. FIG. 14 shows the fan array fan section in the air-handling system set to operate at 32% of the maximum rated air flow but only consumes 17% of full rated power. These numbers are based on exemplary typical fan operations in a structure. In this embodiment, the array controller 300 creates a second exemplary pattern of "OFF" fan units 200 and "ON" fan units 200 as shown.

#### Real Estate

The fan array fan section in the air-handling section 220 of the present invention preferably uses (60% to 80%) less real estate than prior art discharge plenums 120 (with the hundred series number being prior art as shown in FIG. 1 and the two hundred series number being the present invention as shown in FIG. 3) in air-handling systems. Comparing the prior art (FIG. 1) and the present invention (FIG. 3) shows a graphical representation of this shortening of the airway path 120, 220. There are many reasons that using multiple smaller fan units 200 can reduce the length of the airway path 120, 220. For example, reducing the size of the fan unit 100, 200 and motor 108, 208 reduces the length of the discharge plenum 110, 210. Similarly, reducing the size of the inlet cone 104, 204 reduces the length of the inlet plenum 112, 212. The length of the discharge plenum 110, 210 can also be reduced because air from the fan array fan section in the air-handling system of the present invention is substantially uniform whereas the prior art air-handling system has points of higher air velocity and needs time and space to mix so that the flow is uniform by the time it exits the air-handling compartment 102, 202. (This can also be described as the higher static efficiency in that the present invention eliminates the need for settling means downstream from the discharge of a prior art fan system because there is little or no need to transition from high velocity to low velocity.) The fan array fan section in the air-handling system takes in air from the inlet plenum 212 more evenly and efficiently than the prior art air-handling system so that the length of the inlet plenum 112, 212 may be reduced.



For purposes of comparison, the first exemplary structure set forth in the Background of the Invention (a structure requiring 50,000 cubic feet per minute of air flow at a pressure of six (6) inches water gage) will be used. Using the first exemplary structure, an exemplary embodiment of the present invention could be served by a nominal discharge plenum 210 of 89 inches high by 160 inches wide and 30 to 36 inches long (as compared to 106 to 112 inches long in the prior art embodiments). The discharge plenum 210 would include a 3x4 fan array fan section in the air-handling system such as the one shown in FIG. 6) having 12 fan units 200. The space required for each exemplary fan unit 200 would be a rectangular cube of approximately 24 to 30 inches on a side depending on the array configuration. The airway path 220 is 42 to 48 inches (as compared to 88 to 139 inches in the prior art embodiments).

For purposes of comparison, the second exemplary structure set forth in the Background of the Invention (a structure requiring 26,000 cubic feet per minute of air flow at a pressure of two (2) inches water gage) will be used. Using the second exemplary structure, an exemplary embodiment of the present invention could be served by a nominal discharge plenum 210 of 84 inches high by 84 inches wide, and and 30 to 36 inches long (as compared to 94 to 100 inches long in the prior art embodiments). The discharge plenum would include a 3x3 fan array fan section in the air-handling system (such as the one shown in FIG. 7) having 9 fan units 200. The space required for each exemplary fan unit 200 would be a rectangular cube of approximately 24 to 30 inches on a side depending on the array configuration. The airway path 220 is 42 to 48 inches (as compared to 71 to 95 inches in the prior art embodiments).

#### Reduced Production Costs

It is generally more cost effective to build the fan array fan section in the air-handling system of the present invention as compared to the single fan unit 100 used in prior art air-handling systems. Part of this cost savings may be due to the fact that individual fan units 200 of the fan array can be mass-produced. Part of this cost savings may be due to the fact that it is less expensive to manufacture smaller fan units



200. Whereas the prior art single fan units 100 were generally custom built for the particular purpose, the present invention could be implemented on a single type of fan unit 200. In alternative embodiments, there might be several fan units 200 having different sizes and/or powers (both input and output). The different fan units 200 could  
5 be used in a single air-handling system or each air-handling system would have only one type of fan unit 200. Even when the smaller fan units 200 are custom made, the cost of producing multiple fan units 200 for a particular project is almost always less than the cost of producing a single large prior art fan unit 100 for the same project. This may be because of the difficulties of producing the larger components and/or the cost of  
10 obtaining the larger components necessary for the single large prior art fan unit 100. This cost savings also extends to the cost of producing a smaller air-handling compartment 202.

In one preferred embodiment of the invention, the fan units 200 are modular such that the system is "plug and play." Such modular units may be  
15 implemented by including structure for interlocking on the exterior of the fan units 200 themselves. Alternatively, such modular units may be implemented by using separate structure for interlocking the fan units 200. In still another alternative embodiment, such modular units may be implemented by using a grid system into which the fan units 200 may be placed.

#### 20 Reduced Operating Expenses

The fan array fan section in the air-handling system of the present invention preferably are less expensive to operate than prior art air-handling systems because of greater flexibility of control and fine tuning to the operating requirements of  
25 the structure. Also, by using smaller higher speed fan units 200 that require less low frequency noise control and less static resistance to flow.

#### Increased Efficiency

The fan array fan section in the air-handling system of the present  
30 invention preferably is more efficient than prior art air-handling systems because each

small fan unit 200 can run at peak efficiency. The system could turn individual fan units 200 on and off to prevent inefficient use of particular fan units 200. It should be noted that an array controller 300 could be used to control the fan units 200. As set forth above, the array controller 300 turns off certain fan units 200 and runs the remaining fan units 200 at peak efficiency.

#### Redundancy

Multiple fan units 200 add to the redundancy of the system. If a single fan unit 200 breaks down, there will still be cooling. The array controller 300 may take disabled fan units 200 into consideration such that there is no noticeable depreciation in cooling or air flow rate. This feature may also be useful during maintenance as the array controller 300 may turn off fan units 200 that are to be maintained offline with no noticeable depreciation in cooling or air flow rate.

#### Sound Attenuation Advantages

The high frequency sound of the small fan units 200 is easier to attenuate than the low frequency sound of the large fan unit. Because the fan wall has less low frequency sound energy, shorter less costly sound traps are needed to attenuate the higher frequency sound produced by the plurality of small fan units 200 than the low frequency sound produced by the single large fan unit 100. The plurality of fan units 200 will each operate in a manner such that acoustic waves from each unit will interact to cancel sound at certain frequencies thus creating a quieter operating unit than prior art systems.

#### Reduced Vibration

The multiple fan units 200 of the present invention have smaller wheels with lower mass and create less force due to residual unbalance thus causing less vibration than the large fan unit. The overall vibration of multiple fan units 200 will transmit less energy to a structure since individual fans will tend to cancel each other due to slight differences in phase. Each fan unit 200 of the multiple fan units 200

manage a smaller percentage of the total air handling requirement and thus produce less turbulence in the air stream and substantially less vibration.

#### Alternative Embodiments

5           As mentioned, in one preferred embodiment of the invention, the fan units 200 are modular such that the system is "plug and play." Such modular units may be implemented by including structure for interlocking on the exterior of the fan units 200 themselves. Alternatively, such modular units may be implemented by using separate structure for interlocking the fan units 200. In still another alternative embodiment, such  
10 modular units may be implemented by using a grid system into which the fan units 200 may be placed.

FIG. 16 shows an embodiment using an exemplary grid system 230 into which the fan units 200 may be placed. In this embodiment the grid may be positioned and/or built within the air-handling compartment 202. The fan units 200 may then be  
15 positioned into the grid openings. One advantage of this configuration is that individual fan units 200 may be easily removed, maintained, and/or replaced. This embodiment uses an exemplary unique motor mount 232 that supports the motor 208 without interfering with air flow therearound. As shown, this exemplary motor mount 232 has a plurality of arms that mount around the fan inlet cone 204. It should be noted that the  
20 dimensions of the grid are meant to be exemplary. The grid may be constructed taking into consideration that the fan units 200 in the present invention may be spaced with as little as 20% of a fan wheel diameter between the fan units 200.

FIG. 17 shows an embodiment using either a grid system or modular units 240 using separate structure (not shown) for interlocking the fan units 200. In this  
25 exemplary embodiment, each of the fan units 200 are mounted on a more traditional motor mount 242 within its own fan unit chamber 244. In one preferred embodiment, the fan unit 200 and motor mount 242 are preferably suspended within their own fan unit chamber 244 such that there is an air relief passage 246 therebelow. This air relieve passage 246 tends to improve air flow around the fan units 200.

The fan unit chambers 244 shown in FIG. 17 may include one or more interior surface made from or lined with an acoustically absorptive material or "insulation surface" 248. Going against conventional industry wisdom that surfaces cannot be placed in close proximity with the fan units 200, the present invention places one or more insulation surfaces 248 at least partially around each fan unit 200 without disrupting air flow. The insulation surfaces 248 may include one or more of the sides, top, bottom, front, or back. Exemplary types of insulation include, but are not limited to traditional insulation board (such as that made from inorganic glass fibers (fiberglass) alone or with a factory-applied foil-scrim-kraft (FSK) facing or a factory-applied all service jacket (ASJ)) or alternative insulation such as open cell foam such as that disclosed in U.S. Patent Application No. 10/606,435, which is assigned to the assignee of the present invention, and which the disclosure of which is hereby incorporated by reference herein. Together, the insulation surfaces 248 on the fan unit chambers 244 tend to function as a coplanar silencer. Some of the benefits of using the coplanar silencer include (1) no added airway length for splitters, (2) no pressure drop, and/or (3) relatively low cost. The acoustic advantages of this and other embodiments make the present invention ideal for use in concert halls, lecture halls, performing arts centers, libraries, hospitals, and other applications that are acoustically sensitive.

Although FIG. 17 shows the discharge plenum 210 positioned within the fan unit chambers 244, alternative embodiments of fan unit chambers 244 could enclose the inlet plenum 212, or at least partially enclose both the inlet plenum 212 and the discharge plenum 210. Still other alternative embodiments of fan unit chambers 244 may have grid or wire surfaces (that increase the safety of the present invention) or be open (that would reduce costs).

FIG. 18 shows an array of dampeners 250 that may be positioned either in front of or behind the fan units 200 to at least partially prevent back drafts. In the shown exemplary embodiment, the dampeners 250 include a plurality of plates, each plate positioned on its own pivot. In the shown exemplary embodiment, the plurality of plates slightly overlap each other. The shown embodiment is constructed such that when air is flowing through the fan units 200, the plates are in the open position and when the air

stops, gravity pulls the plates into the closed position. Preferably, each of the dampeners 250 operates independently such that if some of the fan units 200 are ON and some of the fan units 200 are OFF, the dampeners 250 can open or close accordingly. Although shown as a simple mechanical embodiment, alternative  
5 embodiments could include structure that is controlled electronically and/or remotely from the dampeners 250.

It should be noted that FIG. 4 shows a 4x6 fan array fan section in the air-handling system having twenty-four fan units 200, FIG. 5 shows a 5x5 fan array fan section in the air-handling system having twenty-five fan units 200, FIG. 6 shows a 3x4  
10 fan array fan section in the air-handling system having twelve fan units 200, FIG. 7 shows a 3x3 fan array fan section in the air-handling system having nine fan units 200, and FIG. 8 shows a 3x1 fan array fan section in the air-handling system having three fan units 200. It should be noted that the array may be of any size or dimension of more than two fan units 200. It should be noted that although the fan units 200 may be  
15 arranged in a single plane (as shown in FIG. 3), an alternative array configuration could contain a plurality of fan units 200 that are arranged in a staggered configuration (as shown in FIG. 15) in multiple planes. It should be noted that cooling coils (not shown) could be added to the system either upstream or downstream of the fan units 200. It should be noted that, although shown upstream from the fan units 200, the filter bank  
20 122, 222 could be downstream.

It should be noted that an alternative embodiment would use a horizontally arranged fan array. In other words, the embodiments shown in FIGS. 3-15 could be used horizontally or vertically or in any direction perpendicular to the direction of air flow. For example, if a vertical portion of air duct is functioning as the air-handling  
25 compartment 202, the fan array may be arranged horizontally. This embodiment would be particularly practical in an air handling compartment for a return air shaft.

It should be noted that the fan section 214 may be any portion of the airway path 220 in which the fan units 200 are positioned. For example, the fan units 200 may be situated in the discharge plenum 210 (as shown), the inlet plenum 212, or  
30 partially within the inlet plenum 212 and partially within the discharge plenum 210. It

should also be noted that the air-handling compartment 202 may be a section of air duct.

The terms and expressions that have been employed in the foregoing specification are used as terms of description and not of limitation, and are not intended  
5 to exclude equivalents of the features shown and described or portions of them. The scope of the invention is defined and limited only by the claims that follow.

## WHAT IS CLAIMED IS:

1 1. A fan array fan section in an air-handling system comprising:

2 (a) at least three fan units;

3 (b) said at least three fan units arranged in a fan array;

4 (c) an air-handling compartment within which said fan array of fan units  
5 is positioned; and

6 (d) an array controller for controlling said at least three fan units to run  
7 at substantially peak efficiency.  
8

1 2. The fan array fan section in an air-handling system of claim 1,  
2 wherein said at least three fan units are plenum fans.  
3

1 3. The fan array fan section in an air-handling system of claim 1,  
2 wherein said air-handling compartment has an airway path, said airway path being less  
3 than 72 inches.  
4

1 4. The fan array fan section in an air-handling system of claim 1,  
2 wherein said at least three fan units are a plurality of fan units arranged in a fan array  
3 configuration selected from the group consisting of:

4 (a) a true array configuration;

5 (b) a spaced pattern array configuration;

6 (c) a checker board array configuration;

7 (d) rows slightly offset array configuration;

8 (e) columns slightly offset array configuration; and

9 (f) a staggered array configuration.  
10

1 5. The fan array fan section in an air-handling system of claim 1,  
2 wherein said at least three fan units are plenum fans include at least two vertically  
3 arranged fan units.

4

1           6.     The fan array fan section in an air-handling system of claim 1,  
2 wherein each of said at least three fan units is positioned within a fan unit chamber.

3

1           7.     The fan array fan section in an air-handling system of claim 1,  
2 wherein each of said at least three fan units is suspended within a fan unit chamber  
3 such that there is an air relief passage therebelow.

4

1           8.     The fan array fan section in an air-handling system of claim 1,  
2 wherein each of said at least three fan units is positioned within a fan unit chamber  
3 having at least one insulation surface.

4

1           9.     The fan array fan section in an air-handling system of claim 1,  
2 wherein each of said at least three fan units are mounted in a grid system.

3

1           10.    The fan array fan section in an air-handling system of claim 1,  
2 wherein each of said at least three fan units has a fan wheel diameter, wherein spacing  
3 between said at least three fan units is less than 60% of said fan wheel diameter.

4

1           11.    A fan array fan section in an air-handling system comprising:  
2 (a)    an air-handling compartment;  
3 (b)    a plurality of fan units;  
4 (c)    said plurality of fan units arranged in a fan array;  
5 (d)    said fan array having at least one fan unit arranged vertically on at  
6 least one other fan unit.  
7 (e)    said fan array positioned within said air-handling compartment.

8

1           12.    The fan array fan section in an air-handling system of claim 11  
2 further comprising an array controller programmed to operate said plurality of fan units  
3 at peak efficiency.



4  
1 13. The fan array fan section in an air-handling system of claim 11,  
2 wherein said plurality of fan units are plenum fans.  
3

1 14. The fan array fan section in an air-handling system of claim 11,  
2 wherein said air-handling compartment has an airway path, said airway path being less  
3 than 72 inches.  
4

1 15. The fan array fan section in an air-handling system of claim 11,  
2 wherein said plurality of fan units are arranged in a fan array configuration selected from  
3 the group consisting of:

- 4 (a) a true array configuration;  
5 (b) a spaced pattern array configuration;  
6 (c) a checker board array configuration;  
7 (d) rows slightly offset array configuration;  
8 (e) columns slightly offset array configuration; and  
9 (f) a staggered array configuration.  
10

1 16. The fan array fan section in an air-handling system of claim 11,  
2 wherein each of said plurality of fan units is positioned within a fan unit chamber.  
3

1 17. The fan array fan section in an air-handling system of claim 11,  
2 wherein each of said plurality of fan units is suspended within a fan unit chamber such  
3 that there is an air relief passage therebelow.  
4

1 18. The fan array fan section in an air-handling system of claim 11,  
2 wherein each of said plurality of fan units is positioned within a fan unit chamber having  
3 at least one insulation surface.  
4

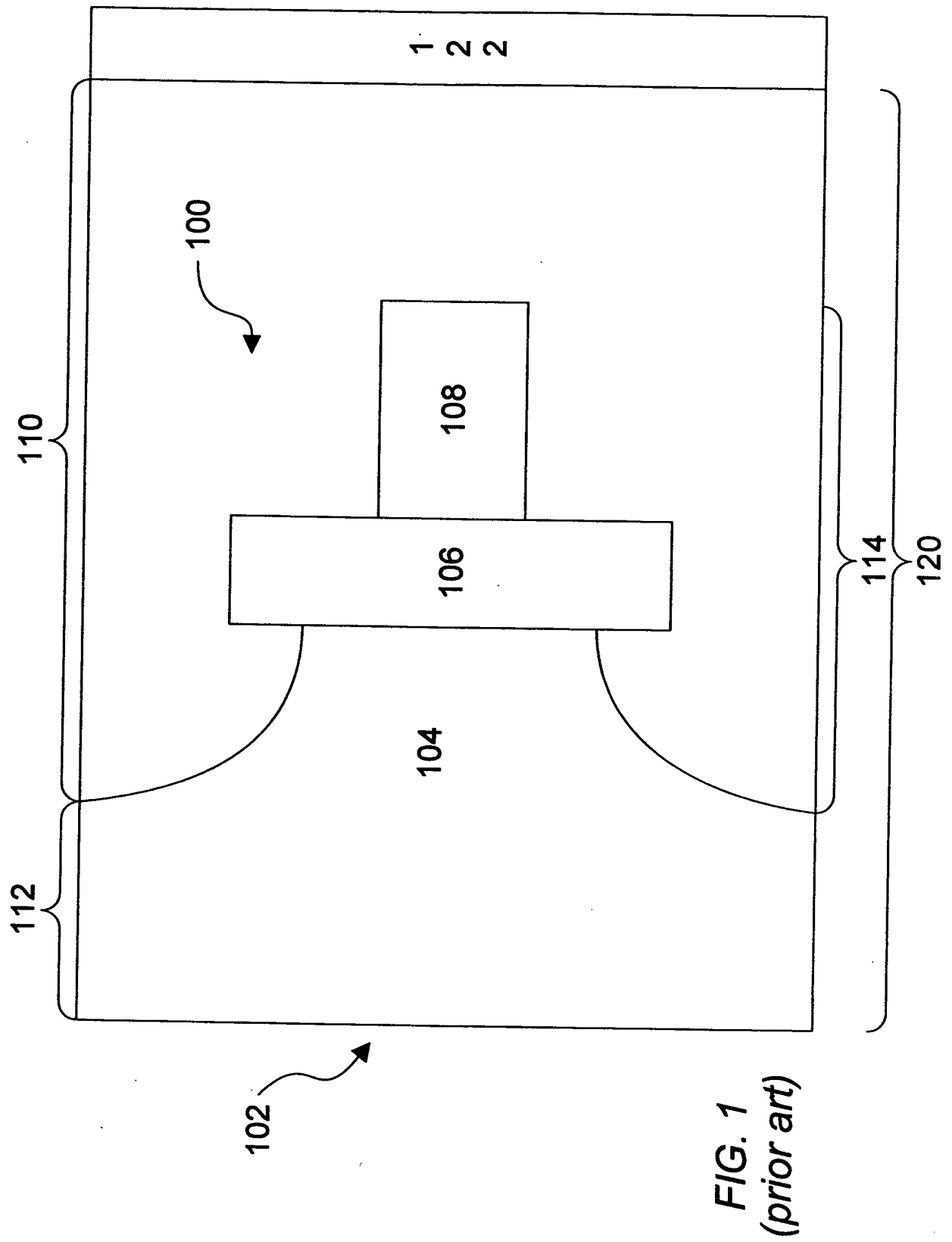
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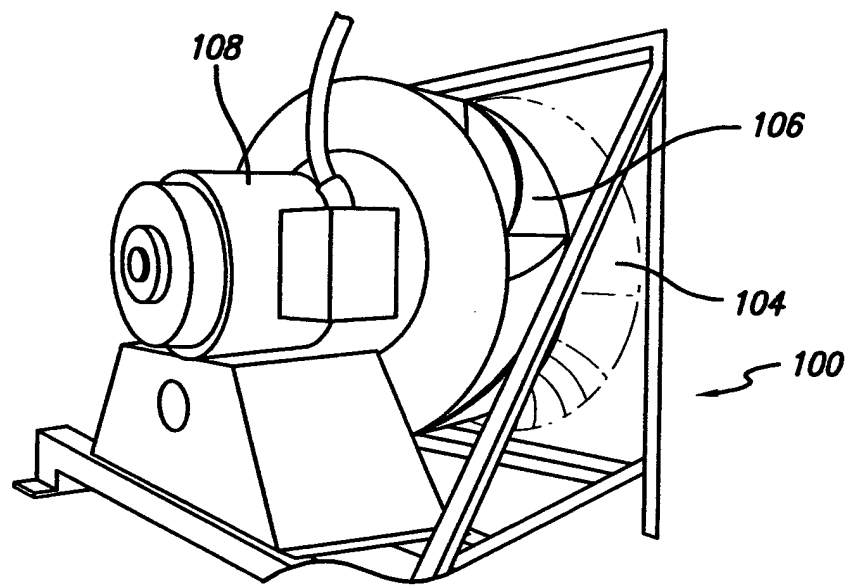
1                   19.    The fan array fan section in an air-handling system of claim 11,  
2 wherein each of said plurality of fan units is mounted in a grid system.  
3

1                   20.    The fan array fan section in an air-handling system of claim 11,  
2 wherein each of said plurality of fan units has a fan wheel diameter, wherein spacing  
3 between said plurality of fan units is less than 60% of said fan wheel diameter.  
4

**FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS  
ABSTRACT OF THE DISCLOSURE**

5                   A fan array fan section in an air-handling system includes a plurality  
of fan units arranged in a fan array and positioned within an air-handling  
compartment. One preferred embodiment may include an array controller  
programmed to operate the plurality of fan units at peak efficiency. The plurality  
of fan units may be arranged in a true array configuration, a spaced pattern array  
10 configuration, a checker board array configuration, rows slightly offset array  
configuration, columns slightly offset array configuration, or a staggered array  
configuration.





*FIG. 2*  
*(prior art)*

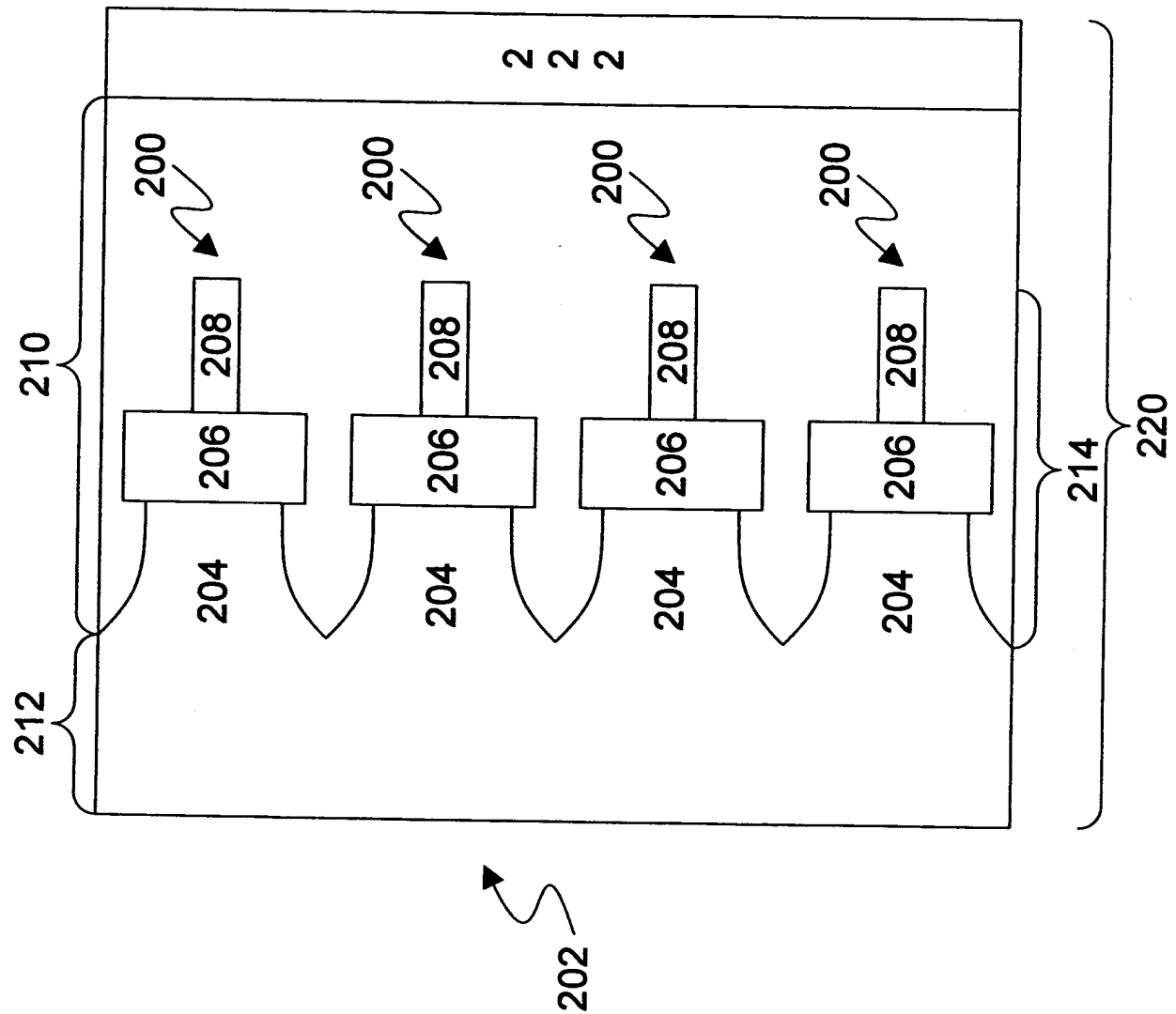


FIG. 3

200	200	200	200	200	200
200	200	200	200	200	200
200	200	200	200	200	200
200	200	200	200	200	200

202

FIG. 4

200	200	200	200	200
200	200	200	200	200
200	200	200	200	200
200	200	200	200	200
200	200	200	200	200

202

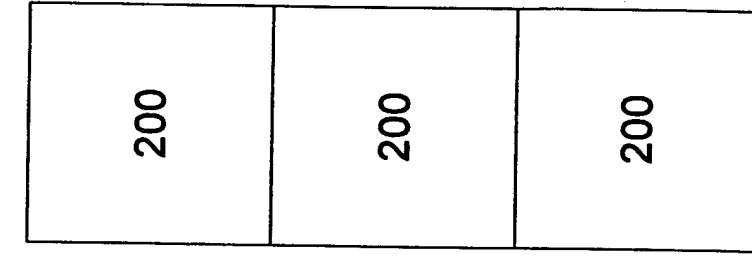
FIG. 5



200	200	200	200
200	200	200	200
200	200	200	200

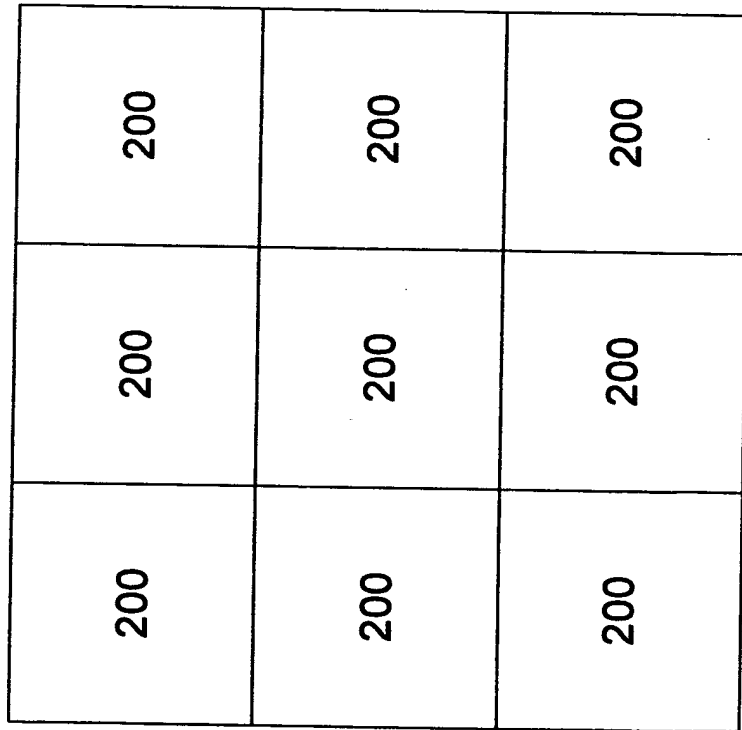
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FIG. 6



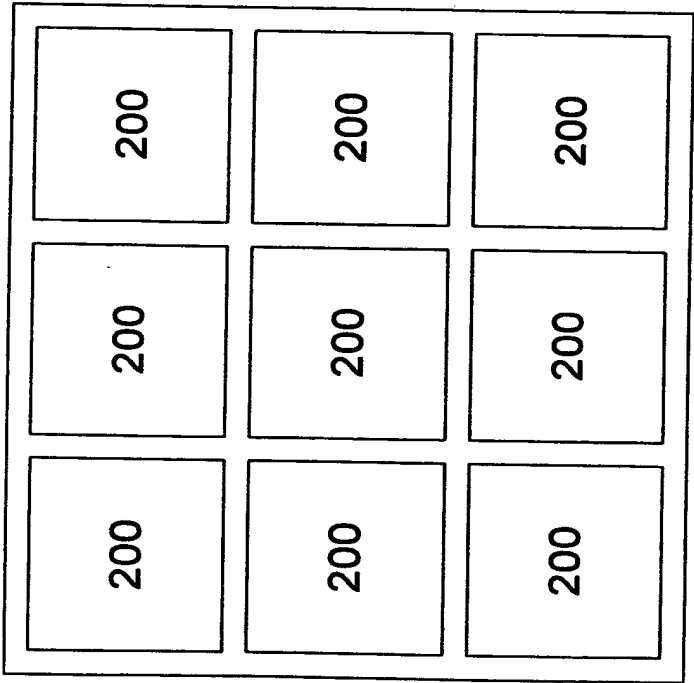
202

FIG. 8



202

FIG. 7



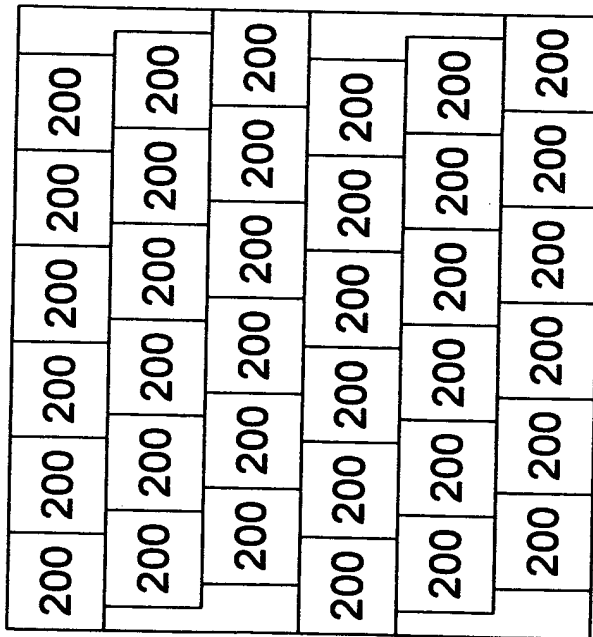
202

FIG. 9

	200		200		200
200		200		200	
	200		200		200
200		200		200	
	200		200		200
200		200		200	

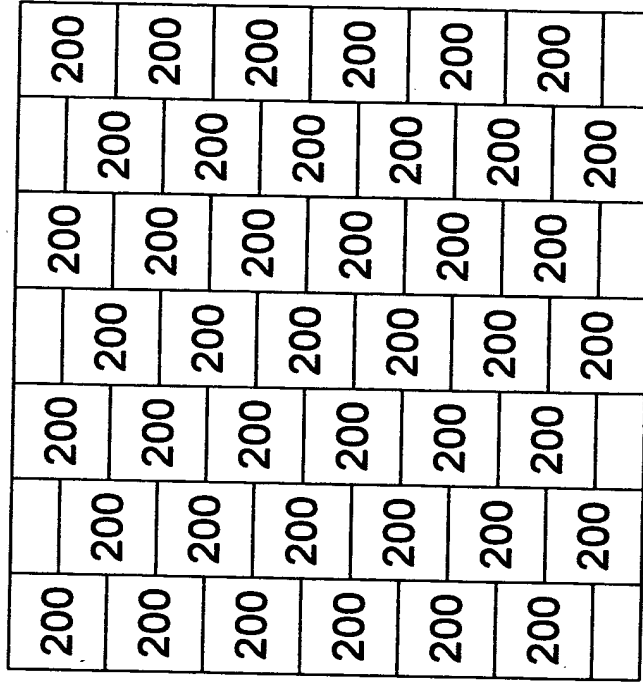
202

FIG. 10



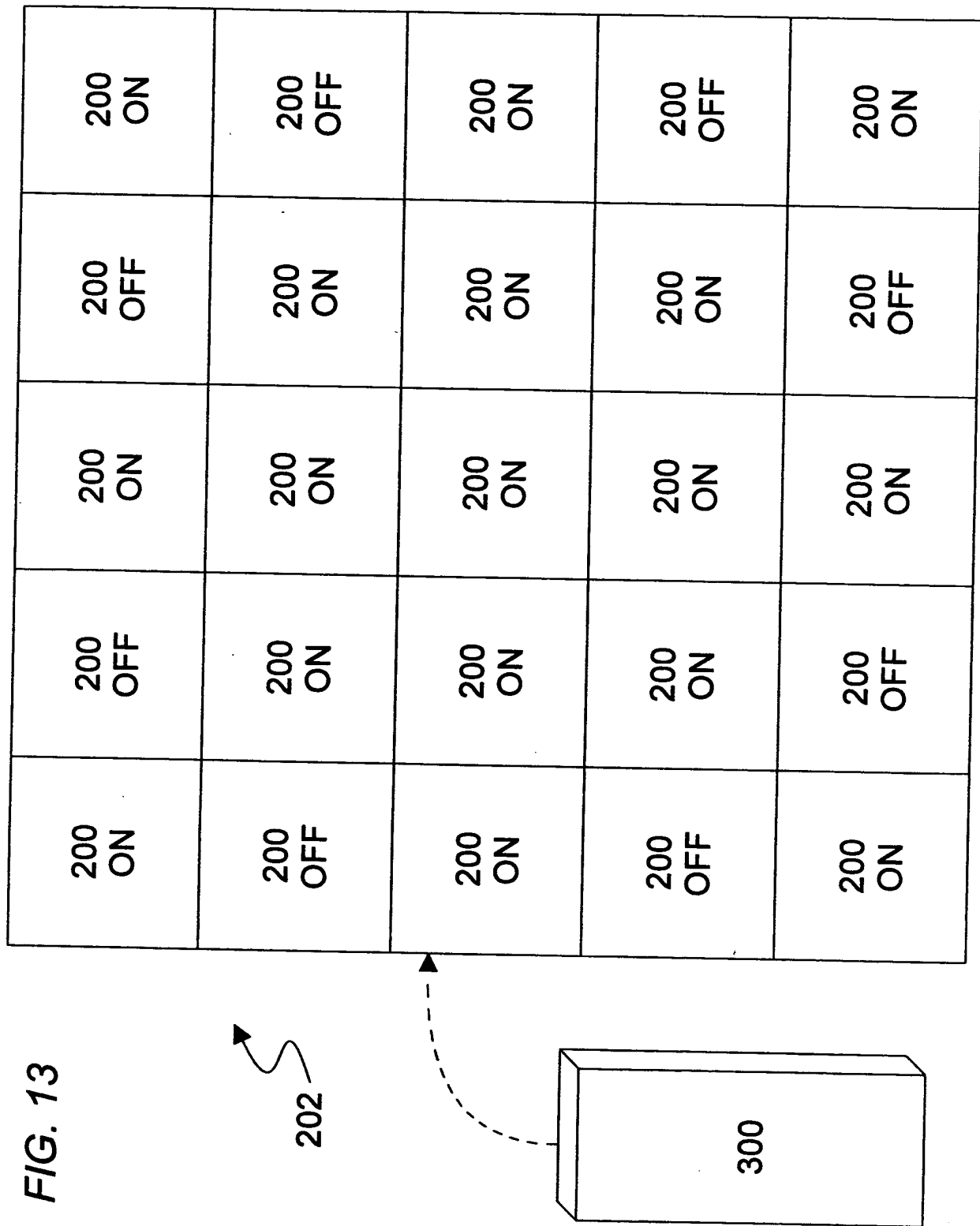
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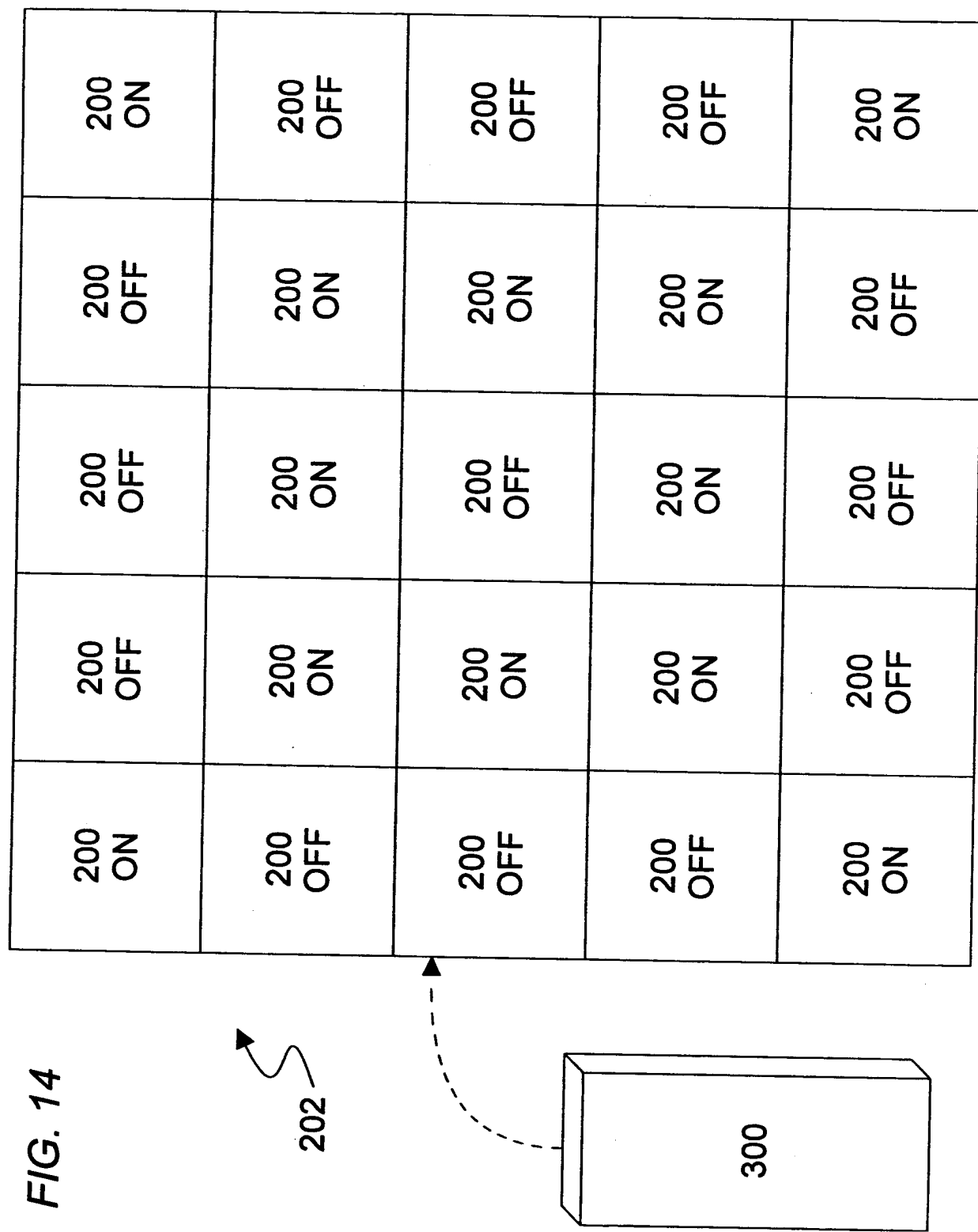
FIG. 11



202

FIG. 12





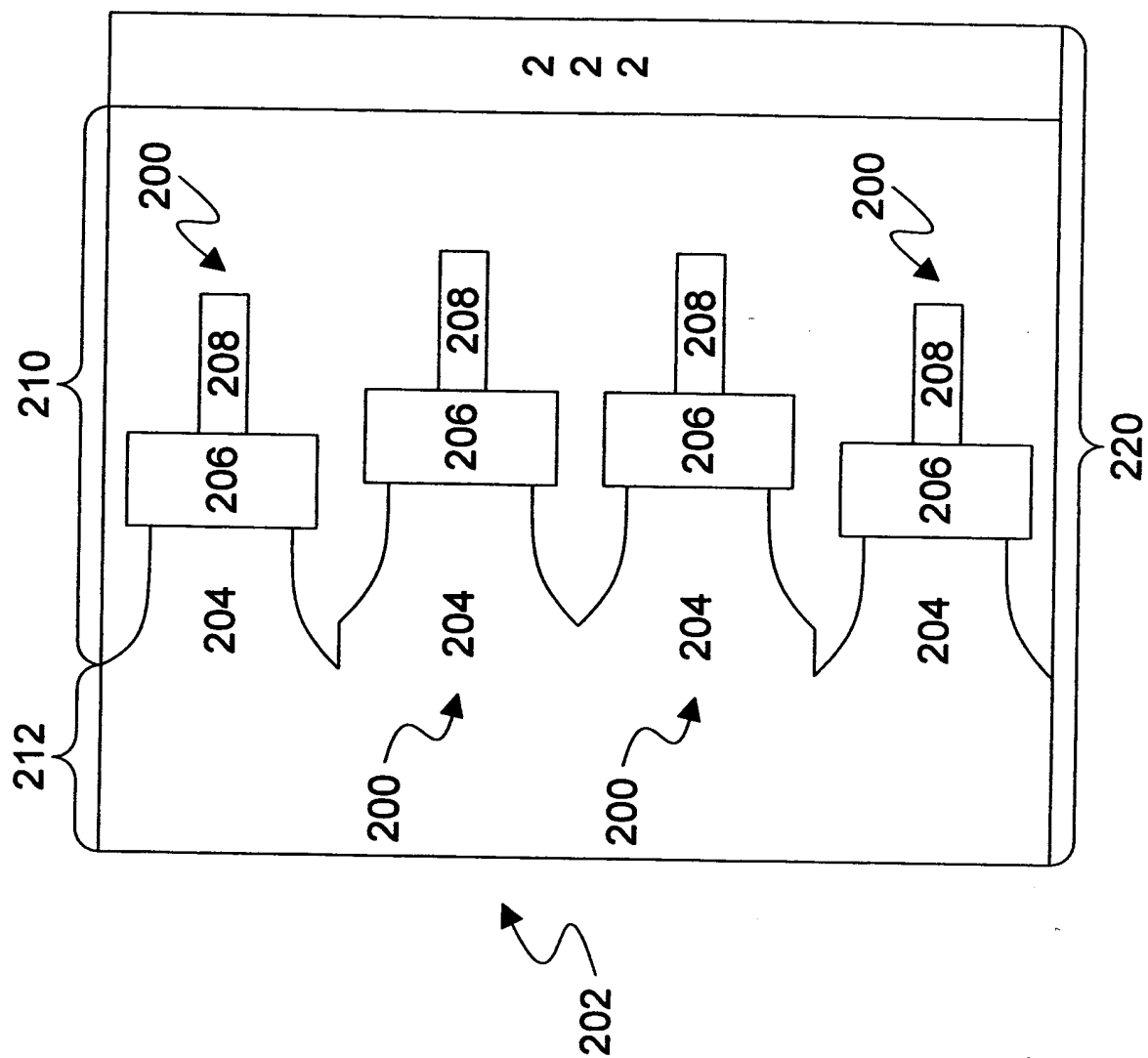
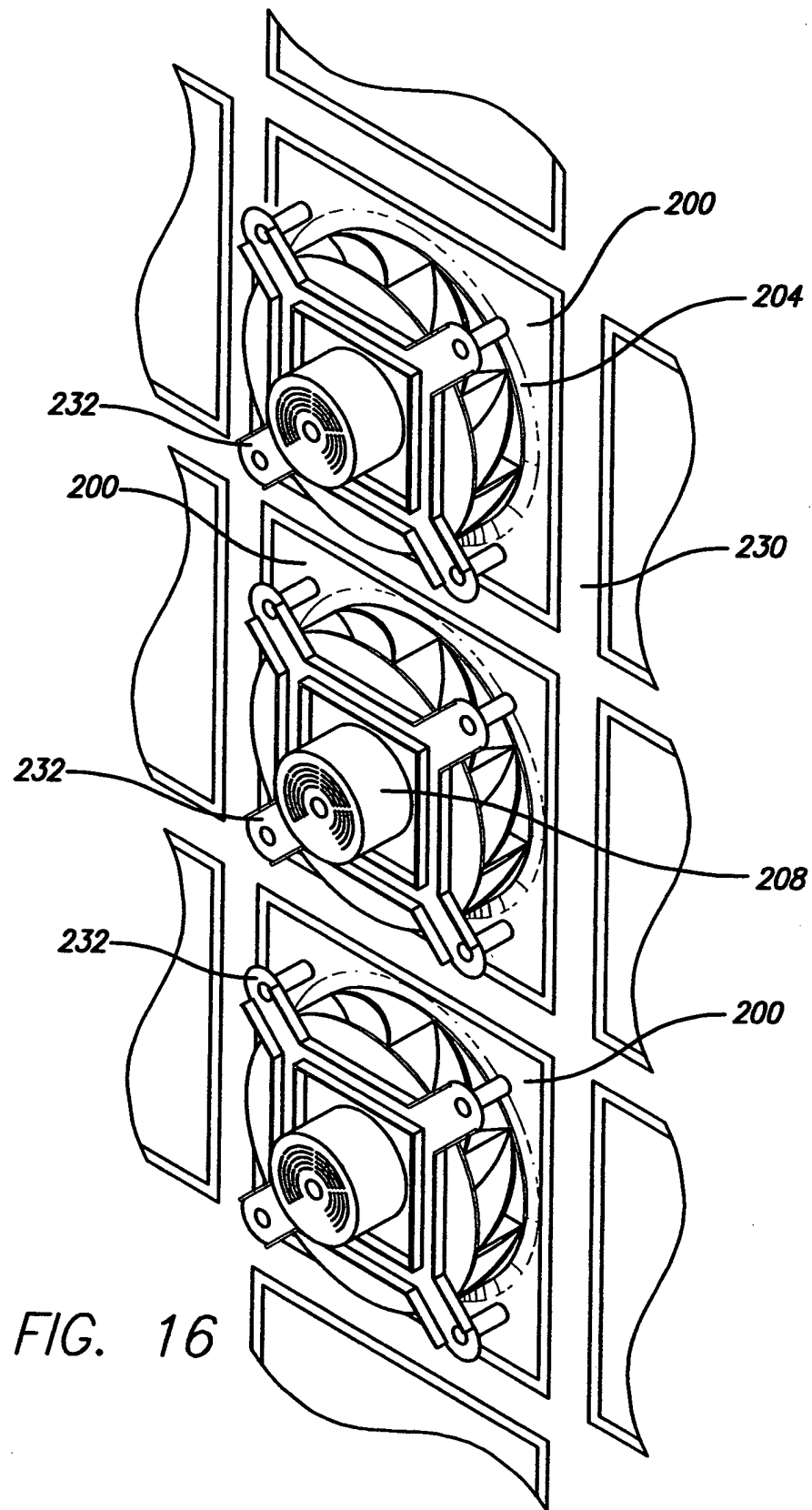


FIG. 15





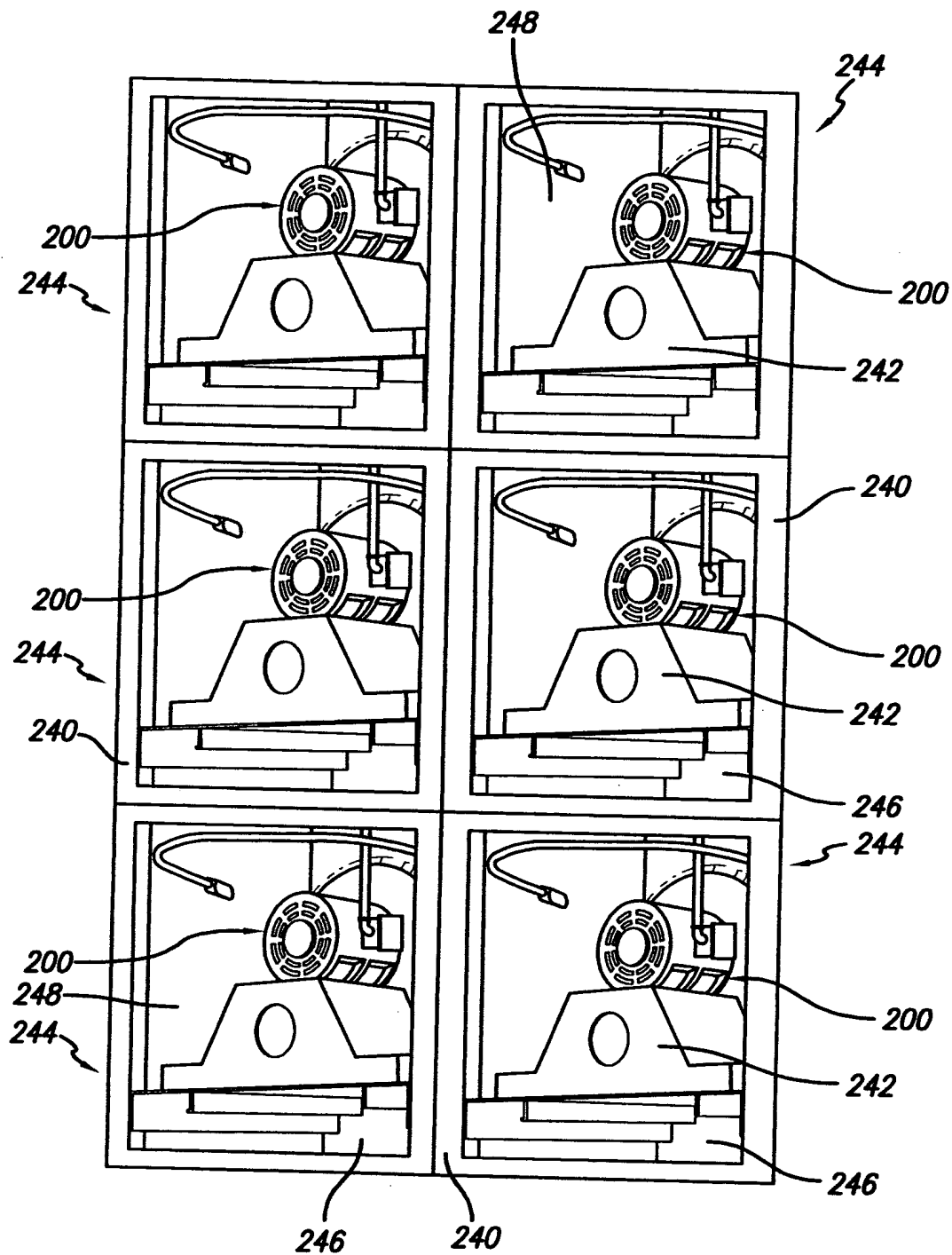
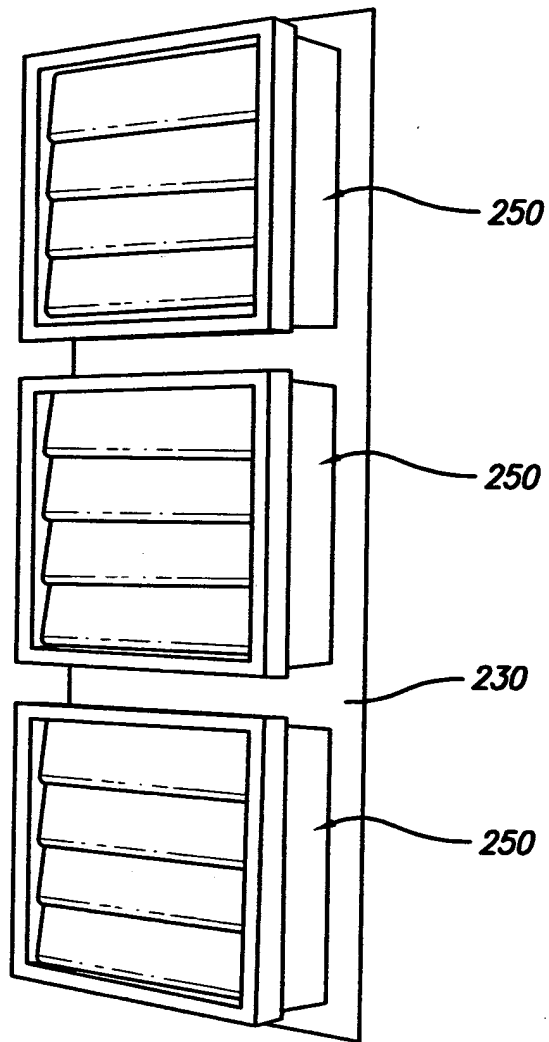


FIG. 17



*FIG. 18*

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Filing Date	March 22, 2004
First Named Inventor	Hopkins
Title	FAN ARRAY FAN SECTION IN AIR-HANDLING SYSTEMS
Art Unit	
Examiner Name	
Attorney Docket Number	HuntFanAvr1

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Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)**SIGNATURE of Applicant or Assignee of Record**

Name	Lawrence G. Hopkins		
Signature	<i>Lawrence G. Hopkins</i>		
Date	03-22-2004	Telephone	(503) 740-7610

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below.

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Art Unit	
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Attorney Docket Number	HuntFanArray

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Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/06)

## SIGNATURE of Applicant or Assignee of Record

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Signature	<i>[Signature]</i> 3-22-04		
Date	03-22-2004	Telephone	(603) 504-8533

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